PDMI PREPRINT — 12/1997

CP VIOLATION PROBLEM AND UNCONDITIONAL TESTS OF FUNDAMENTAL DISCRETE SYMMETRIES T, CPT IN RIGOROUS QUANTUM DYNAMICS BEYOND THE APPROXIMATE LEE–OEHME–YANG THEORY

Leonid A. KHALFIN

Russian Academy of Sciences
Steklov Mathematical Institute
St. Petersburg Department
Fontanka 27, St. Petersburg 191011, Russia
E-mail: khalfin@pdmi.ras.ru

July 21, 1997

ABSTRACT

The CP-violation problem, and unconditional tests of discrete symmetries T, CPT investigated in the exact Quantum Theory (QT) beyond the usually used Lee–Oehme–Yang (LOY) theory, which was based on famous Weisskopf–Wigner (W.W.) approximation. It were derived new unconditional CP-violation effects, independent from known before, new unconditional tests of the CPT and T invariances, new results for correlations. Corresponding general results were obtained for $K^0-\bar{K}^0$, $B^0-\bar{B}^0$, $D^0-\bar{D}^0$ mesons. On the base of these new theoretical results given some proposals for experiments by CP LEAR and ϕ, B, τ factories. New results are interesting not only for the CP-violation problem itself, but also for possibilities to test violation of the standard quantum dynamics connected with ideas of quantum gravity.

Based on the talk at 2-nd International Symposium on Symmetries in Subatomic Physics, June 25–28, 1997, Seatle, USA, and on the invited lecture at FNAL, July 3, 1997, Batavia, USA

1. The CP-violation problem is one of the oldest [1] unsolved problem of modern physics. Very specific properties of K^0–$\bar{K}^0$, B^0–$\bar{B}^0$, D^0–$\bar{D}^0$ mesons are an overlapping of their mass distributions. From this fact follows that such mesons are very sensitive "interferometer" in particle physics, which gives possibility for: a) detail investigation of the CP-violation problem, including the ϵ'/ϵ problem, and so for testing of possible "new physics" beyond the Standard Model (see, for example, some articles in [2], [2a]), b) tests of the fundamental CPT, T-invariances problems [2], [2a], c) tests of the Superposition Principle [3–6], d) tests of a new (non-Hamiltonian) quantum dynamics, connected with ideas of the quantum gravity (see, for example, [7–9] and recent reports [10, 11]), e) general tests of QT – classical Bell's and quantum Tsirelson's inequalities [12]. Up to now for theoretical investigations of these fundamental problems usually used the standard LOY theory [13], which essentially was based on the famous W.W. approximation (see, for example, [2, 2a, 9]). From the fundamental character of these problems it is evident that it will be very essential to investigate they in the exact QT beyond the LOY theory. It was done in author's works from 1968 up to now (see, for example, [14–18] and another references therein, and also some works [3a,19–21], which were induced by author's works). It is very essential that exact theory beyond the LOY theory gives some new qualitative effects, but not only small quantitative perturbations of the effects known before from the LOY theory.

In this paper the exact QT means the usually used Hilbert Space (HS) formulation of Quantum Theory and all results of this paper were obtained within this usual HS QT. But some times ago was proposed another Rigged Hilbert Space (RHS) formulation of QT (see [22] and other references therein), which gives different (from the usual HS QT) predictions to the theory of unstable states (particles) and in general to the theory of nonstationary solutions of the QT. Because the investigations of the CP-violation problem use the deep properties of the nonstationary solutions of the QT this open the possibilities by experiment to test what formulation of the QT-usual HS or RHS is more adequate to the reality. I shall point specially such new predictions of the HS QT, which are different from the predictions of the RHS QT.

In this paper I cannot give all new results with corresponding mathematical proofs (see for some proofs the original works). I shall give here mainly the standing points of the problems, main theoretical results with the proofs and experimental consequences from these results. I specially point the differences between these new results and known before from the LOY theory and from the RHS QT.

2. For the usual (one-level) unstable particles a new result beyond the W.W. approximation is the nonexponentiality of a decay law (first derived in [23]). This nonexponentiality was induced some delicate experimental works and was verified for some specially prepared unstable states (see corresponding references in [24]). For the usual (one-level) unstable states (particles) with simple Breit-Wigner energy (mass) distributions

$$\omega(m) \backsim [(m - m_0)^2 + \Gamma^2]^{-1}$$

such nonexponentiality from the dimensless point of view has the order of Γ/m_0, which is very small. From this does not follows with necessarity that such small nonexponentiality cannot be amplified for some special problems (for example, for Quantum Zeno Effect (QZE)– Man Made Physics(MMPh), see corresponding references in [24]), but in this paper I shall not investigate such possibilities. At the same time for such unusual (multilevel) unstable particles like K^0–$\bar{K}^0$, B^0–$\bar{B}^0$, D^0–$\bar{D}^0$ we have many dimensless parameters, some of which are not very small like $\Gamma_L/\Gamma_S \simeq 10^{-3}$, $\Gamma_L/\Delta m \simeq 10^{-3}$ for K^0–$\bar{K}^0$ and even bigger $\Gamma_L/\Gamma_S \simeq 1$, $\Gamma/\Delta m \simeq 7 * 10^{-1}$ for B^0–$\bar{B}^0$, $\Gamma_L/\Gamma_S \simeq 1$ (more accurate it is for $B_d^0 - -\bar{B}_d^0$), $\Gamma/\Delta m \simeq 8 * 10^{+1}$ for D^0–$\bar{D}^0$. So from the dimensless point of view it is possible that there exist some new effects in the exact theory beyond the LOY (W–W approximarion), which are not too small. It was proved (see, for example, [14–18]) that such possibilities are true in some natural model assumptions. All results in this paper I shall give in main for K^0–$\bar{K}^0$, but corresponding results are true also, for B^0–$\bar{B}^0$, D^0–$\bar{D}^0$. I shall point some specific results for B^0–$\bar{B}^0$, D^0–$\bar{D}^0$, which follow from the specific properties of these mesons.

The obtained results are general results for the multi-level unstable physical systems (particles) with violation of some discrete symmetries (like CP, baryon conservation law, lepton conservation law, the flavor conservation law). So analogical results are true for the neutron-antineutron oscillations, neutrino oscillations.

3. As it was proved [14–18] the main new effects exist for K^0– $\bar{K}^0$ (and B^0– $\bar{B}^0$, D^0 – –$\bar{D}^0$) correlations data. From this reason it was proposed by author in 1968 [25] correlations factory experiments like $e^-e^+ \to \phi \to K^0\bar{K}^0(K_SK_L)$ (independently from Lipkin proposal [26]). Analogical new possibilities are open also by CP LEAR [27]. In close future it will be possible to do correlations experiments by Frascati ϕ factory [2] and later by SLAC and KEK B factories, and τ-charm factory.

4. The main statements of the LOY theory for the CP-violation inside CPT- invariant case (corresponding results are true also for CPT-noninvariant case, but in the main part of this paper I shall investigate the CPT-invariant case) are: there exist such superpositions K_S and K_L of K^0, $\bar{K}^0$

$$\begin{cases} |K_S\rangle = p\,|K^0\rangle + q\,|\bar{K}^0\rangle,\ |K_L\rangle = p\,|K^0\rangle - q\,|\bar{K}^0\rangle, \\ \langle K_S|K_S\rangle = \langle K_L|K_L\rangle = |p|^2 + |q|^2 = 1,\ \langle K_S|K_L\rangle = |p|^2 - |q|^2 \neq 0 \quad (CP), \\ \langle K_S|K_L\rangle = \langle K_L|K_S\rangle \qquad (CPT), \end{cases} \tag{1}$$

which are usual (one-level) unstable particles, such that:

a) K_S, K_L (contrary to K^0, $\bar{K}^0$) *do not regenerate* to each other in the vacuum, but only decay

$$\begin{cases} |K_S(t)\rangle = p_{SS}(t)|K_S\rangle + \sum_F \sigma_{SF}(t)|F\rangle, \\ |K_L(t)\rangle = p_{LL}(t)|K_L\rangle + \sum_F \sigma_{LF}(t)|F\rangle, \end{cases} \tag{2}$$

where $|F\rangle$ are the state vectors of the decay products, for which it is true that $\langle F|K_S\rangle = 0 = \langle F|K_L\rangle$.

b) the decay laws of K_S, K_L are simple exponential ($t \geqq 0$):

$$p_{SS}(t) = \exp(-im_St - \Gamma_St), \qquad p_{LL}(t) = \exp(-im_Lt - \Gamma_Lt). \tag{2a}$$

In (1) p, q are some complex numbers, which are connected with m_S, m_L, Γ_S, Γ_L through non-Hermitian effective Hamiltonian H_{eff} (W.W. approximation).

Let us now use the spectral language for discription of K_S, $K_L\,(K^0, \bar{K}^0)$

$$H\,|\varphi_\alpha(m)\rangle = m\,|\varphi_\alpha(m)\rangle, \qquad \langle\varphi_\beta(m')|\varphi_\alpha(m)\rangle = \delta_\alpha^\beta\,\delta(m - m'), \tag{3}$$

where H is Hermitian (contrary to H_{eff})) Hamiltonian of *all* including interactions with absolute continious spectrum. We have

$$\begin{cases} \big|\,K_S\,\big\rangle = \displaystyle\int\limits_{\mathrm{Spec}\,H} \sum_{\alpha} c_{S,\alpha}(m)\,\big|\,\varphi_\alpha(m)\big\rangle\, dm, \\ \big|\,K_L\,\big\rangle = \displaystyle\int\limits_{\mathrm{Spec}\,H} \sum_{\beta} c_{L,\beta}(m)\,\big|\,\varphi_\beta(m)\big\rangle\, dm, \\ \big|\,K^0\,\big\rangle = \displaystyle\int\limits_{\mathrm{Spec}\,H} \sum_{\alpha} c_{K^0,\alpha}(m)\big|\,\varphi_\alpha(m)\big\rangle\, dm, \\ \big|\,\bar{K}^0\,\big\rangle = \displaystyle\int\limits_{\mathrm{Spec}\,H} \sum_{\beta} c_{\bar{K}^0,\beta}(m)\,\big|\,\varphi_\beta(m)\big\rangle\, dm. \end{cases} \tag{4}$$

The LOY theory is equivalent to the assumption that the mass (energy) distributions $\omega_S,\ \omega_L$ of $K_S,\ K_L$ are simple one-pole (Breit–Wigner)

$$\begin{cases} \omega_S(m) = \sum_\alpha \big|\,c_{S,\alpha}(m)\big|^2 = \dfrac{\Gamma_S}{\pi}\,\big[(m-m_S)^2\,+\,\Gamma_S^2\big]^{-1}, \qquad \Gamma_S \ll m_S, \\ \omega_L(m) = \sum_\beta \big|\,c_{L,\beta}(m)\big|^2 = \dfrac{\Gamma_L}{\pi}\,\big[(m-m_L)^2\,+\,\Gamma_L^2\big]^{-1}, \qquad \Gamma_L \ll m_L. \end{cases} \tag{5}$$

From (5) it follows exponential decay laws (2a) if we neglect by very small nonexponential terms [23]. In the LOY theory it is true the Bell–Steinberger (B.St.) unitarity relation [28]

$$\big\langle K_S\,\big|\,K_L\big\rangle\big[i\,(m_S-m_L)\,-\,(\Gamma_S+\Gamma_L)\big] = \sum_F \big\langle F\,\big|\,T\,\big|\,K_S\big\rangle^*\big\langle F\,\big|\,T\,\big|\,K_L\big\rangle, \tag{6}$$

which usually used as CPT and T invariance tests [2]. Let us point out that for CP-invariant theory the B. St. relation is trivial $0=0$.

From the main statements (1), (2), (2a) of the LOY theory follow usual formulas ($t \geqq 0$)

$$\begin{aligned} \big|\,K^0(t)\big\rangle &= \exp(-iHt)\big|\,K^0\,\big\rangle \\ &= p_{K^0K^0}(t)\big|\,K^0\,\big\rangle\,+\,p_{\bar{K}^0K^0}(t)\big|\,\bar{K}^0\,\big\rangle\,+\sum_F \sigma_{K^0F}(t)\,\big|\,F\big\rangle \\ &= \frac{1}{2}\,\big[\,\exp(-im_St-\Gamma_St)\,+\,\exp(-im_Lt-\Gamma_Lt\big]\,\big|\,K^0\,\big\rangle \\ &\quad+\,\frac{q}{2p}\,\big[\,\exp(-im_St-\Gamma_St)\,-\,\exp(-im_Lt-\Gamma_Lt)\big]\,\big|\,\bar{K}^0\,\big\rangle \\ &\qquad+\sum_F \sigma_{K^0F}(t)\,\big|\,F\big\rangle; \end{aligned} \tag{6a}$$

$$\begin{aligned} \big|\,\bar{K}^0(t)\big\rangle &= \exp(-iHt)\,\big|\,\bar{K}^0\big\rangle \\ &= p_{\bar{K}^0\bar{K}^0}(t)\,\big|\,\bar{K}^0\big\rangle\,+\,p_{K^0\bar{K}^0}\,\big|\,K^0\big\rangle\,+\sum_F \sigma_{\bar{K}^0F}(t)\,\big|\,F\big\rangle \\ &= \frac{1}{2}\big[\,\exp\big(-im_S-\Gamma_St\big)\,+\,\exp\big(-im_Lt-\Gamma_Lt\big)\big]\,\big|\,\bar{K}^0\big\rangle \\ &\quad+\,\frac{p}{2q}\,\big[\,\exp\big(-im_St-\Gamma_St\big)-\exp\big(-im_Lt-\Gamma_Lt\big)\big]\,\big|\,K^0\big\rangle \\ &\qquad+\sum_F \sigma_{\bar{K}^0F}(t)\,\big|\,F\big\rangle. \end{aligned} \tag{6b}$$

Such expressions usually used for the interpretation three classical effects of the CP-violation [1]: 1) 2π-meson decay mode for long times ($t \simeq \tau_L \gg \tau_S$), 2) interference in the 2π decay mode, 3) charge asymmetry in the semileptonic decay modes (in main for long time $t \simeq \tau_L$). From expressions (6a, b) all results of the LOY theory follow.

Comment 1: We see such identity from (6a, b):

$$p_{K^0K^0}(t) = p_{\bar{K}^0\bar{K}^0}(t). \tag{7}$$

Comment 2: The vacuum regeneration amplitudes $p_{\bar{K}^0K^0}(t)$, $p_{K^0\bar{K}^0}(t)$ have the same time dependence. So in the LOY theory the ratio

$$r(t) = p_{\bar{K}^0K^0}/p_{K^0\bar{K}^0} = \text{const} = q^2/p^2 \neq 1. \tag{8}$$

5. Now I formulate the main new results of the exact QT beyond the LOY theory. In 1972 [29] it was proved new unconditional test of the CPT-invariance

$$\omega_{K^0}(m) = \omega_{\bar{K}^0}(m), \tag{9a}$$

$$p_{K^0K^0}(t) = p_{\bar{K}^0\bar{K}^0}(t), \tag{9b}$$

which gives the generalization of the famous Lee–Yang theorem on the identity of masses and lifetimes of particles and antiparticles to identity of the mass distributions ω_{K^0}, $\omega_{\bar{K}^0}$ of "unusual" unstable particles K^0, $\bar{K}^0$. It is essential that this test is independent (contrary to B. St. test (6)) from the CP-violation or not. The obtained unconditional test (9a), (9b) is true for *any* mass distributions of K^0,$\bar{K}^0$ (K_S,K_L). Test (9b) was also derived by Kabir [3], but within the LOY theory (see (7)), and so for one-pole Breit- Wigner mass distributions (5) of K_S,K_L.

Main Theorem (M.TH.). *Within the CPT-invariant, but CP-noninvariant QT there do not exist any superpositions K_S, K_L of K^0, $\bar{K}^0$ (see (1)) such that*

A. they do not regenerate (contrary to K^0, $\bar{K}^0$) to each other in the vacuum,

B. they have the single one-pole (Breit–Wigner) mass distributions and the corresponding exponential decay laws.

It is true the analog of this M.TH. with statement A. for the CPT-noninvariant case [30].

Proof [14-18]. I shall give here only the proof of the statement A.

We have

$$\left\{ \begin{array}{l} \big|K^0(t)\big\rangle = p_{K^0K^0}(t)\big|K^0\big\rangle + p_{\bar{K}^0K^0}(t)\big|\bar{K}^0\big\rangle + \sum_F \sigma_{K^0F}(t)\big|F\big\rangle \\ \big|\bar{K}^0(t)\big\rangle = p_{\bar{K}^0\bar{K}^0}(t)\big|\bar{K}^0\big\rangle + p_{K^0\bar{K}^0}(t)\big|K^0\big\rangle + \sum_F \sigma_{\bar{K}^0F}(t)\big|F\big\rangle \end{array} \right. \tag{10}$$

On the base of the fundamental Superposition Principle we obtain

$$\left\{ \begin{array}{l} \big|K_S(t)\big\rangle = \exp(-iHt)\big|K_S\big\rangle = p\big|K^0(t)\big\rangle + q\big|\bar{K}^0(t)\big\rangle \\ \big|K_L(t)\big\rangle = \exp(-iHt)\big|K_L\big\rangle = p\big|K^0(t)\big\rangle - q\big|\bar{K}^0(t)\big\rangle \end{array} \right. \tag{11}$$

Now we use (10), reformulate $\big|K^0\big\rangle$, $\big|\bar{K}^0\big\rangle$ through $\big|K_S\big\rangle$, $\big|K_L\big\rangle$ and after long but simple algebraic transformations obtain such expressions for $\big|K_S(t)\big\rangle$, $\big|K_L(t)\big\rangle$

$$\left\{ \begin{array}{l} \big|K_S(t)\big\rangle = \frac{1}{2}[p_{K^0K^0}(t) + \frac{q}{p}p_{K^0\bar{K}^0}(t) + p_{\bar{K}^0\bar{K}^0}(t) + \frac{p}{q}p_{\bar{K}^0K^0}(t)]\big|K_S\big\rangle \\ +\frac{1}{2}[p_{K^0K^0}(t) + \frac{q}{p}p_{K^0\bar{K}^0}(t) - p_{\bar{K}^0\bar{K}^0}(t) - \frac{p}{q}p_{\bar{K}^0K^0}(t)]\big|K_L\big\rangle \\ +\sum_F \sigma_{SF}(t)\big|F\big\rangle \\ = p_{SS}(t)\big|K_S\big\rangle + p_{LS}(t)\big|K_L\big\rangle + \sum_F \sigma_{SF}(t)\big|F\big\rangle \end{array} \right. \tag{12a}$$

$$\begin{cases} \left|K_L(t)\right\rangle = \frac{1}{2}[p_{\bar{K}^0\bar{K}^0}(t) - \frac{q}{p}p_{K^0\bar{K}^0}(t) + p_{K^0K^0}(t) - \frac{p}{q}p_{\bar{K}^0K^0}(t)]\left|K_L\right\rangle \\ +\frac{1}{2}[p_{K^0K^0}(t) - \frac{q}{p}p_{K^0\bar{K}^0}(t) - p_{\bar{K}^0\bar{K}^0}(t) + \frac{p}{q}p_{\bar{K}^0K^0}(t)]\left|K_S\right\rangle \\ +\sum_F \sigma_{LF}(t)\left|F\right\rangle \\ = p_{LL}(t)\left|K_L\right\rangle + p_{SL}(t)\left|K_S\right\rangle + \sum_F \sigma_{LF}(t)\left|F\right\rangle \end{cases} \tag{12b}$$

So, in general, we see the possibility of the vacuum regeneration of $\left|K_S\right\rangle$ and $\left|K_L\right\rangle$ if the amplitudes of the vacuum regenerations $p_{SL}(t)$, $p_{LS}(t)$

$$\begin{cases} p_{SL}(t) = \frac{1}{2}[p_{K^0K^0}(t) - \frac{q}{p}p_{K^0\bar{K}^0}(t) - p_{\bar{K}^0\bar{K}^0}(t) + \frac{p}{q}p_{\bar{K}^0K^0}(t)] \\ p_{LS}(t) = \frac{1}{2}[p_{K^0K^0}(t) + \frac{q}{p}p_{K^0\bar{K}^0}(t) - p_{\bar{K}^0\bar{K}^0}(t) - \frac{p}{q}p_{\bar{K}^0K^0}(t)] \end{cases} \tag{13}$$

are nonzero. Let us now investigate such possibility. From the CPT-invariance (see (9b)) we obtain on the base of (13a,b) for $t \in [0, \infty)$

$$\begin{cases} p_{SL}(t) = \frac{1}{2}[\frac{p}{q}p_{\bar{K}^0K^0}(t) - \frac{q}{p}p_{K^0\bar{K}^0}(t)] \\ p_{LS}(t) = \frac{1}{2}[\frac{q}{p}p_{K^0\bar{K}^0}(t) - \frac{p}{q}p_{\bar{K}^0K^0}(t)] \end{cases} \tag{14}$$

If we remember the main formulas (6a,b) of the LOY theory for $p_{\bar{K}^0K^0}(t)$,$p_{K^0\bar{K}^0}(t)$, then we see from (14) that in the LOY theory (W–W approximation) the vacuum regeneration of $\left|K_S\right\rangle$ and $\left|K_L\right\rangle$ is, as well known, absent. Let we assume now that it is true also in the exact QT beyond the LOY theory

$$p_{SL}(t) = 0, p_{LS}(t) = 0; \qquad \text{for} \qquad t \in [0, \infty) \tag{15}$$

From this assumption on the base of (14) we obtain

$$\frac{p}{2q}p_{\bar{K}^0K^0}(t) = \frac{q}{2p}p_{K^0\bar{K}^0}(t); \qquad \text{for} \quad t \in [0, \infty) \tag{16}$$

But for $p_{\bar{K}^0K^0}(t)$, $p_{K^0\bar{K}^0}(t)$ we obtain such expressions through the Fourier integrals

$$\begin{cases} p_{\bar{K}^0K^0}(t) = \left\langle \bar{K}^0 \middle| K^0(t)\right\rangle = \left\langle \bar{K}^0\right| \exp(-iHt)\left|K^0\right\rangle \\ = \int\limits_{\text{Spec } H} \sum_\beta c^*_{\bar{K}^0,\beta}(m)c_{K^0,\beta}(m)\exp(-imt)dm \\ p_{K^0\bar{K}^0}(t) = \left\langle K^0 \middle| \bar{K}^0(t)\right\rangle = \left\langle K^0\right| \exp(-iHt)\left|\bar{K}^0\right\rangle \\ = \int\limits_{\text{Spec } H} \sum_\alpha c^*_{K^0,\alpha}(m)c_{\bar{K}^0,\alpha}(m)\exp(-imt)dm \end{cases} \tag{17}$$

Now we use the fundamental Spectral Principle of QT

$$SpecH \geqslant 0 \tag{18}$$

Let us point here that in the LOY theory this fundamental Spectral Principle of QT was not taking into acount. But we use (18) in the exact HS QT. From (16) and (18) on the base of Titchmarsh theorem follows that the function

$$f_{LS}(t) = \frac{q}{2p}p_{K^0\bar{K}^0}(t) - \frac{p}{2q}p_{\bar{K}^0K^0}(t) \tag{19}$$

is the boundary value of an analytical function in the $Im \quad t < 0$ complex t half-plane. From the assumption that K_S and K_L donot regenerate to each other in the vacuum (see (15)) it follows that

$$f_{LS}(t) = 0, \qquad \text{for} \quad t \in [0, \infty) \tag{20}$$

But from (18) and analiticity (the Paley-Wiener theorem) it follows directly that $f_{LS}(t)$ must be identically zero for all $t \in (-\infty, +\infty)$

$$f_{LS}(t) = 0 \qquad \text{for} \quad t \in (-\infty, +\infty) \tag{21}$$

Then from the definition of $f_{LS}(t)$ (19) and the expressions (17) by the inverse Fourier transform we obtain

$$\frac{q}{2p}\sum_{\alpha} c^*_{K^0,\alpha}(m) c_{\bar{K}^0,\alpha}(m) = \frac{p}{2q}\sum_{\beta} c^*_{\bar{K}^0,\beta}(m) c_{K^0,\beta}(m), \quad \text{for} \quad m \in [0, \infty) \tag{22}$$

or

$$\frac{p^2}{q^2} = \frac{\sum_\alpha c^*_{K^0,\alpha}(m) c_{\bar{K}^0,\alpha}(m)}{\sum_\beta c^*_{\bar{K}^0,\beta}(m) c_{K^0,\beta}(m)} \qquad \text{for} \quad m \in [0, \infty) \tag{23}$$

Then immediately from (23) it follows that

$$|p|^2 = |q|^2 \Rightarrow \langle K_S | K_L \rangle = |p|^2 - |q|^2 = 0 \tag{24}$$

in contradiction to the initial assumption of the M.TH. on the CP-violation. By this contradiction we proved the part A. of the M.TH.

The proof of the part B. of the M.TH. based [14-18] on such condition of the admissibility of the $\omega_S(m)$, $\omega_L(m)$ mass distributions

$$\begin{cases} < K_S|K_L > [\omega_S(m) + \omega_L(m)] \\ = \sum_\alpha [c^*_S(m) c_L(m) + c_S(m) c^*_L(m)] \end{cases} \tag{9c}$$

which directly follows from (9a).

Comment 1. The M.TH. is true for *any* mass distributions of K^0, $\bar{K}^0(K_S, K_L)$ and so for *any* Hamiltonian H or for *any* model of interactions (superweak , Standard Model, ...), which induced the CP-violation.

Comment 2. In the CPT and CP invariant QT the M.TH. is trivially not true (because in this case $K_S = K^1_0$, $K_L = K^2_0$).

Comment 3. The B.St. unitarity relation (6) is not true in the exact theory. This Comment is essential, because the B.St. unitarity relation was proposed (see corresponding references in [2]) as the test of the fundamental CPT and T invariances.

From the M.TH. follows directly (see, for example, [14–18]) that contrary to the LOY theory prediction (8) the ratio $r(t)$ *must be* time-dependent

$$r(t) \neq \text{const} \tag{25}$$

and this is the first new, independent from three classical [1], CP-violaton effect. As follows from the Comment 1, this new CP-violation effect is theoretically unconditional. Moreover, as it follows from the M.TH. the ratio $r(t)$ cannot be time independent for *any* interval of time t. So it is possible to test the CP-violation also for small times interval, where statistics is much bigger than for the long times ($t \simeq \tau_L \gg \tau_S$), where was derived the first CP-violation effect for the 2π decay mode. Recent results from the CP LEAR experiment [31] not contradict to this new prediction, but the accuracy of the CP LEAR experiment up to now is not sufficient for more exact conclusion.

6. From the method of the proof of the M.TH. follows also very

General Theorem (G.TH.). *Let* $|a\rangle$ *and* $|b\rangle$ *are unstable states. If the amplitude* $p_{ab}(t) = \langle a|\exp(-iHt)|b\rangle$ *and the amplitude of the inverse (time-reversal) regeneration* $p_{ba}(t) = \langle b|\exp(-iHt)|a\rangle$ *have the same time-dependence*

$$r(t) = p_{ab}(t)/p_{ba}(t) = const \tag{26}$$

then $|r| = 1$.

In recent article [3a] this theorem was called as Khalfin's theorem. In a separate paper I shall give some critical comments to the investigation of the meannig of this theorem in [3a]. This G.TH. is interesting independently of the CP-violation problem and as follows from the formulation is independent from the CPT and CP invariances assumptions. The G.TH. is essential for the problem of T-invariance and could be used from this point of view also for experiments on the neutron- antineutron and neutrinos oscillations. If $|a\rangle = |K^0\rangle$ and $|b\rangle = |\bar{K}^0\rangle$ then this G.TH. transforms to (26). In [3] the condition (8), which was obtained within the approximate LOY theory, was proposed as direct test of the T-noninvariance. As follows from the M.TH. and G.TH. the direct test of the T-nonivariance within the exact QT predicts that $p_{\bar{K}^0 K^0}$ and $p_{K^0 \bar{K}^0}$ must be different not only by magnitudes (as predicted in [3]), but also by time-dependence. This essential to point out, because Kabir test (8) will be tested in future factory experiment [2] and was tested by CP LEAR. As pointed above the today accuracy of the CP LEAR experiment [31] is not suffiient for distinguish between the approximate LOY (8) and exact theory (25) predictions.

In [3] also was proposed as direct, independent from the CPT and CP-invariance problems, test of the fundamental Superposition Principle of the QT such test

$$p_{\bar{K}^0 K^0}(t)/p_{K^0 \bar{K}^0}(t) = \text{const} \tag{27}$$

Analogical test (for two times case) was proposed in [4]. As follows from the M.TH. such tests cannot be exactly tests of such fundamental Superposition Principle. Contrary to this, as follows from the proof of the M.TH., the Superposition Principle was essentially used and so the new effect of the CP-violation (25) can be used also as the direct test of the Superposition Principle of QT.

7. We see that the M.TH. directly *contradicts* to the main statements of the approximate LOY theory and also to the predictions of the RHS formulation of the QT [22]. Because the LOY theory is the approximation within the standard HS QT we must solve such two principal problems: 1) to explain why independently of this contradiction the LOY theory gave true interpretation of three classical effects of the CP-violation [1], 2) to propose new experiments, which could distinguish between predictions of the LOY and the exact HS QT theories. From another side if the predictions of the exact HS QT, different from the predictions of the approximate LOY theory and from the predictions of the RHS QT, should be experimentally verified, then it supports usually used standard HS QT.

First of all, as follows from the M.TH. the superpositions K_S, K_L (1) regenerate to each other in the vacuum, so

$$\begin{cases} |K_S(t)\rangle = p_{SS}(t)|K_S\rangle + p_{LS}(t)|K_L\rangle + \sum_F \sigma_{LF}(t)|F\rangle, \\ |K_L(t)\rangle = p_{LL}(t)|K_L\rangle + p_{SL}(t)|K_S\rangle + \sum_F \sigma_{LF}(t)|F\rangle, \end{cases} \tag{28}$$

where the regeneration amplitudes $p_{SL}(t)$, $p_{LS}(t)$ cannot be zero in any interval of time t. Within CPT-invariant, but CP-noninvariant QT it is possible to prove on the base of the G.TH. that the same is true for any superpositions of K^0, $\bar{K}^0$. Now we explain why from the phenomenological point of view, in which p, q, m_S, m_L, Γ_S, Γ_L are phenomenological parameters, the predictions of the LOY theory and the exact theory are the same for the three classical CP-violation effects for usual experiments with pure K^0 (or $\bar{K}^0$) meson. In the LOY theory we have

$$\big|K^0(t)\big\rangle = \frac{1}{2p}\Big[\exp\big(-im_S(t)-\Gamma_S t\big)\,\big|K_S\big\rangle + \exp\big(-im_L t-\Gamma_L t\big)\Big]\,\big|K_L\big\rangle + \sum_F \sigma_{K^0F}(t)\big|F\big\rangle. \quad (29)$$

In the exact theory we obtain

$$\big|K^0(t)\big\rangle = \frac{1}{2p}\Big[p_{SS}(t)\,\big|K_S\big\rangle + p_{LS}(t)\,\big|K_L\big\rangle + p_{LL}(t)\,\big|L\big\rangle + p_{SL}(t)\big|K_S\big\rangle\Big] + \sum_F \sigma_{K^0F}(t)\big|F\big\rangle. \quad (30)$$

But if $p_{SS}(t)$, $p_{LL}(t)$, $p_{LS}(t)$, $p_{SL}(t)$ are some superpositions of two functions $\exp\big(-im_S t-\Gamma_S t\big)$, $\exp\big(-im_L t-\Gamma_L t\big)$ (it is true for some models with pole approximation [14–18, 21], see also below 8.), then it is possible on the base of the linearity of (30) to introduce the new superpositions $\widetilde{K}_S$, $\widetilde{K}_L$ such that (30) transforms to

$$\big|K^0(t)\big\rangle = \frac{1}{2p}\Big[\exp(-im_S t-\Gamma_S t)\big|\widetilde{K}_S\big\rangle + \exp(-im_L t-\Gamma_L t)\big|\widetilde{K}_L\big\rangle\Big] + \sum_F \sigma_{K^0F}(t)\big|F\big\rangle. \quad (30a)$$

But it is impossible by the *same* $\widetilde{K}_S$, $\widetilde{K}_L$ transforms

$$\big|\bar{K}^0(t)\big\rangle = \frac{1}{2q}\Big[p_{SS}(t)\,\big|K_S\big\rangle + p_{LS}(t)\,\big|K_L\big\rangle - p_{LL}(t)\,\big|K_L\big\rangle - p_{SL}(t)\big|K_S\big\rangle\Big] + \sum_F \sigma_{\bar{K}^0F}(t)\big|F\big\rangle \quad (31)$$

to

$$\big|\bar{K}^0(t)\big\rangle = \frac{1}{2q}\Big[\exp(-im_S t-\Gamma_S t)\big|\widetilde{K}_S\big\rangle - \exp\big(-im_L t-\Gamma_L t\big)\big|\widetilde{K}_L\big\rangle\Big] + \sum_F \sigma_{\bar{K}^0F}(t)\big|F\big\rangle. \quad (31a)$$

From this consideration follows why the LOY theory and the exact theory give the same phenomenological predictions for three classical CP-violation effects for usual experiments with pure K^0 (or $\bar{K}^0$) meson. At the same time from this consideration follows that the predictions of the LOY and the exact theory are $different$ for $K^0-\bar{K}^0$ correlations. The typical example of such different predictions is the prediction of the time dependence for the ratio $r(t)$ (25). Another example of different predictions is that the LOY theory predicts for the CPT-invariant case that the interference term in the 2π decay modes for $K^0(t)$ and $\bar{K}^0(t)$ are only different in the sign. This is not true in the exact theory. Such comments are very essential for the interpretation [31] of CP LEAR experiments on the decay rates of tagged $K^0(t)$ and $\bar{K}^0(t)$ in the $\pi^+\pi^-$ mode. In a separate paper I shall present the very recently derived results on more rigorous interpretation of these CP LEAR experimental data [31].

The essential difference is for factory experiments like

$$e^- e^+ \to \phi \to K_S, K_L(K^0 \bar{K}^0).$$

From the Pauli principle follows (see, for example, [2])

$$|\,\phi\rangle = \frac{1}{\sqrt{2}}\frac{1}{2pq}\big[K_L(\vec{p})\,K_S(-\vec{p}) \;-\; K_S(\vec{p})\,K_L(-\vec{p})\big].$$

Let us investigate decay mode f_1 in the direction $(-\vec{p})$ at the time t_1 correlated with decay mode f_2 in the direction $(\vec{p})$ at time t_2. Let $A(f_1,(-\vec{p}),\,t_1;f_2,(\vec{p}),t_2) = A(f_1,\,t_1;f_2,\,t_2)$ is the corresponding correlation amplitude. In the LOY theory we have [2, 32]

$$A(f_1,t_1;f_2,t_2) = \frac{1}{\sqrt{2}}\frac{1}{2pq}\big[\langle f_1|T||\,K_S\,\rangle\langle f_2|T||\,K_L\,\rangle\,p_{SS}(t_1)\,p_{LL}(t_2) \\ -\,\langle f_1|T||\,K_L\,\rangle\langle f_2|T||\,K_S\,\rangle\,p_{LL}(t_1)\,p_{SS}(t_2)\big]. \quad (32)$$

But in the exact theory, taking into account the vacuum regeneration of K_S, K_L, we obtain

$$A(f_1,t_1;f_2,t_2) = \frac{1}{\sqrt{2}}\frac{1}{2pq}\Big\{\,\big[\langle f_1|T||\,K_S\,\rangle\langle f_2|T||\,K_L\,\rangle p_{SS}(t_1)\,p_{LL}(t_2) \\ -\,\langle f_1|T||\,K_L\,\rangle\langle f_2|T||\,K_S\,\rangle p_{LL}(t_1)\,p_{SS}(t_2)\big] + \\ \langle f_1|T||\,K_L\,\rangle\langle f_2|T||\,K_S\,\rangle\,\big[p_{LS}(t_1)\,p_{SL}(t_2)\big] \;-\; \langle f_1|T||\,K_S\,\rangle\langle f_2|T||\,K_L\,\rangle \\ \big[p_{SL}(t_1)\,p_{LS}(t_2)\big] + \langle f_1|T||\,K_L\,\rangle\langle f_2|T||\,K_L\,\rangle\,\big[p_{LS}(t_1)\,p_{LL}(t_2) - p_{LL}(t_1)\,p_{LS}(t_2)\big] + \\ \langle f_1|T||\,K_S\,\rangle\langle f_2|T||\,K_S\,\rangle\,\big[p_{SL}(t_2)\,p_{SS}(t_1) - p_{SS}(t_2)\,p_{SL}(t_1\big]\Big\}. \quad (33)$$

Last two terms for $t_1 \neq t_2$ are not zero and look as "violation" of the Pauli principle.

8. The new phenomena in the exact theory of the CP-violation problem and the new effects of the CP-violation, as was pointed, are *model independent*. But the magnitudes of these new effects are model dependent and can be very different for different model assumptions. I give here only the estimate of the new CP-violation effect (25) [17]. We have such expressions for the vacuum regeneration amplitudes

$$p_{K^0\bar{K}^0}(t) = \frac{1}{4p^*q}\int\limits_{\mathrm{Spec}\,H}\sum_{\alpha}\Big\{\,\big|\,c_{S,\alpha}(m)\big|^2 - \big|\,c_{L,\alpha}(m)\big|^2 - c^*_{S,\alpha}(m)\,c_{L,\alpha}(m) + \\ c_{S,\alpha}(m)\,c^*_{L,\alpha}(m)\Big\}\,\exp(-imt)\,dm; \quad (34a)$$

$$p_{\bar{K}^0K^0}(t) = \frac{1}{4pq^*}\int\limits_{\mathrm{Spec}H}\sum_{\beta}\Big\{\,\big|\,c_{S,\beta}(m)\big|^2 - \big|\,c_{L,\beta}(m)\big|^2 - c_{S,\beta}(m)c^*_{L,\beta}(m) + \\ c^*_{S,\beta}(m)\,c_{L\beta}(m)\Big\}\,\exp(-imt)\,dm. \quad (34b)$$

The terms $c^*_{S,\alpha}(m)\,c_{L,\alpha}(m)$, $c_{S,\alpha}(m)\,c^*_{L,\alpha}(m)$ depend from the overlapping of K_S,K_L mass distributions and give after integration in (34) the new effects of the order $\Gamma_L/\Delta m \simeq 10^{-3}$.

Let we assume the one-pole mass distributions for K_S and K_L (this contradicts to the statement B. of the M.TH., but taking into account small value of the CP-violation this model assumption is sufficiently good) with including, in general, some nonsingular "preparation" functions $\xi_{S,\alpha}(m)$, $\xi_{L,\beta}(m)$ in $c_{S,\alpha}(m)$, $c_{L,\beta}(m)$

$$\begin{cases} c_{S,\alpha}(m) = \sqrt{\frac{\Gamma_S}{\pi}}\,\frac{\xi_{S,\alpha}(m)\,A_{S,\alpha}}{\big|\xi_{S,\alpha}(m_S - i\Gamma_S)\big|\,(m - m_S + i\Gamma_S)} \\ c_{L,\beta}(m) = \sqrt{\frac{\Gamma_L}{\pi}}\,\frac{\xi_{L,\beta}(m)\,A_{L,\beta}}{\big|\xi_{L,\beta}(m_L - i\Gamma_L)\big|\,(m - m_L + i\Gamma_L)} \\ \qquad \sum_\alpha \big|A_{S,\alpha}\big|^2 = 1\,, \qquad \sum_\beta \big|A_{L,\beta}\big|^2 = 1 \end{cases} \tag{35}$$

It is essential to point out that such preparation functions donot change the exponential terms in the K_S, K_L decay laws (2a). In this model assumption (35) we obtain from (34) by taking into account only the exponential terms such expressions

$$\begin{cases} p_{K^0\bar{K}^0}(t) \simeq \frac{1}{4p^*q}\Big[\exp(-im_S t - \Gamma_S t) \\ [1 + \frac{2i\sqrt{\Gamma_S\Gamma_L}}{(m_L - m_S) + i(\Gamma_S + \Gamma_L)}\sum_\alpha \xi_{L,\alpha}(m_S - i\Gamma_S)A_{S,\alpha}A^*_{L,\alpha}] \\ -\exp(-im_L t - \Gamma_L t) \\ [1 - \frac{2i\sqrt{\Gamma_S\Gamma_L}}{(m_L - m_S) - i(\Gamma_S + \Gamma_L)}\sum_\beta \xi_{S,\beta}(m_L - i\Gamma_L)A^*_{S,\beta}A_{L,\beta}]\Big] \end{cases} \tag{36a}$$

and

$$\begin{cases} p_{\bar{K}^0K^0}(t) \simeq \frac{1}{4pq^*}\Big[\exp(-im_S t - \Gamma_S t) \\ [1 - \frac{2i\sqrt{\Gamma_S\Gamma_L}}{(m_L - m_S) + i(\Gamma_S + \Gamma_L)}\sum_\alpha \xi_{L,\alpha}(m_S - i\Gamma_S)A_{S,\alpha}A^*_{L,\alpha}] \\ -\exp(-im_L t - \Gamma_L t) \\ [1 + \frac{2i\sqrt{\Gamma_S\Gamma_L}}{(m_L - m_S) - i(\Gamma_S + \Gamma_L)}\sum_\beta \xi_{S,\beta}(m_L - i\Gamma_L)A^*_{S,\beta}A_{L,\beta}]\Big] \end{cases} \tag{36b}$$

From (36a,b) we see that the main terms in $p_{K^0\bar{K}^0}(t)$, $p_{\bar{K}^0K^0}(t)$, corresponding to $\big|c_{S,\alpha}(m)\big|^2$, $\big|c_{L,\alpha}(m)\big|^2$ do not change, but in terms corresponding to the new CP-violation effects, connected with $c^*_{S,\alpha}(m)\,c_{L,\alpha}(m)$, $c_{S,\alpha}(m)\,c^*_{L,\alpha}(m)$ we obtain multiplying factors $\xi_{S,\alpha}(m_L - i\Gamma_L)$, $\xi_{L,\beta}(m_S - i\Gamma_S)$. From this fact follows that the new CP-violation effects depend from the mass distribution of K_S at $m \simeq m_L$ and from the mass distribution of K_L at $m \simeq m_S$. In other words we can investigate by the new CP-violation effects the *tails* of mass distributions. Such intriguing possibility *was never* realized before. Today HS QT cannot predicts in general the tails of the mass distributions of the unstable particles and usually used only pole approximations near the pole. From another side the RHS QT assumed from the beginning that the mass distributions of the unstable states are *pure* Breit- Wigner simple pole distributions (5) not only near the poles but for *any* mass m.

If we assume for simplicity the trivial preparation functions $\xi_{S,\alpha}(m) = 1$, $\xi_{L,\beta}(m) = 1$, then after some long but trivial calculations of $\big|p_{\bar{K}^0K^0}(t)\big|^2$,

$\left|p_{K^0\bar{K}^0}(t)\right|^2$, we obtain [17] on the base of (36) such results by taking into account only experimental data of the main 2π decay modes

$$\begin{cases} \left|p_{K^0\bar{K}^0}(t)\right|^2 \simeq \frac{1}{4}\Big\{\exp(-2\Gamma_S t) + \exp(-2\Gamma_L t) - 2\exp(-(\Gamma_S+\Gamma_L)t) \\ \times\Big[\cos(\Delta m\, t) + 0.4\cdot 10^{-3}\sin(\Delta m\, t)\Big]\Big\}, \\ \left|p_{\bar{K}^0 K^0}(t)\right|^2 \simeq \frac{1}{4}\Big\{\exp(-2\Gamma_S t) + \exp(-2\Gamma_L t) - 2\exp(-(\Gamma_S+\Gamma_L)t) \\ \times\Big[\cos(\Delta m\, t) - 0.4\cdot 10^{-3}\sin(\Delta m\, t)\Big]\Big\}. \end{cases} \tag{37}$$

We see that the new effect is of the order of $\Gamma_L/\Delta m \simeq 10^{-3}$ and that in this model the ratio $r(t)$ is *time − dependent*, as predicted by M.TH.

As was pointed above the magnitudes of the new CP-violation effects depend from the model assumptions. For some different from (35) model assumptions [14, 19], in which the derivative of the form factor has the order of $m_{S,L}^{-1}$, the new CP-violation effects are very small as the usual nonexponential terms in the decay law [23].

9. The exact theory beyond the LOY theory is very essential for the investigation the problem of the CPT-invariance, the ϵ'/ϵ problem. As follows directly from the M.TH. the usual [2] experimental tests of the CPT-invariance, formulated in terms of the LOY theory (for example, the B.St. unitarity relation (6) and test [2] based on properties of $\pi^+\pi^-$ and $\pi^0\pi^0$ decay modes of K^0 meson), must indicate the "violation" of the CPT-invariance. But this is not *real* CPT-violation and is the "induced" CPT-violation , connected with the fact that the LOY theory main statements cannot be true in the exact CPT-invariant, but CP-nonivariant HS QT (see [14] and recent [20], [33–35]). At the same time the unconditional test (9) of the CPT-invariance is the exact direct test. It is essential that the unconditional test (9), which was derived within the exact HS QT, as was pointed above (see in 5.), is the same as the direct Kabir's test [3], which was derived in the approximate LOY theory. Recent experimental results from CP LEAR [31] on the base of this direct test support the CPT-invariance. Recently [32] it was pointed very attractive idea for the new tests of the CPT-invariance by investigations the charge asymmetry in the semileptonic decay of K_S in factory correlations. This idea was based on the possibility to create pure K_S in factory correlation. This is true within the LOY theory prediction (see (32)), but, as follows from the M.TH., it cannot be true in the exact theory beyond the W.W. approximation, because K_S regenerate to K_L for any $t \neq 0$ (see (28) and (33)).

We see that some effects within exact CPT-invariant, but CP-noninvariant HS QT are the same as some effects of the CPT and CP-noninvariant approximate LOY theory. The essential question connected with this is such problem - is it true that the exact CPT-invariant QT of the CP-violation is equivalent to the CPT-noninvariant LOY theory? Negative answer to this problem gives such

Theorem [34-36]. *Within CPT invariant, but CP-noninvariant HS QT donot exist any superpositions $\widetilde{K}_S$, $\widetilde{K}_L$ of K^0, $\bar{K}^0$*

$$\big|\widetilde{K}_S\big\rangle = p\big|K^0\big\rangle + q\big|\bar{K}^0\big\rangle, \qquad \big|\widetilde{K}_L\big\rangle = s\big|K^0\big\rangle - r\big|\bar{K}^0\big\rangle \tag{38}$$

such that they donot regenerate to each other in the vacuum for any complex parameters p, q, s, r, which satisfy to natural conditions

$$\begin{cases} \big\langle\widetilde{K}_S\big|\widetilde{K}_S\big\rangle = \big|p\big|^2 + \big|q\big|^2 = 1 = \big|s\big|^2 + \big|r\big|^2 = \big\langle\widetilde{K}_L\big|\widetilde{K}_L\big\rangle \\ \big\langle\widetilde{K}_S\big|\widetilde{K}_L\big\rangle = p^* s + q^* r \neq 0 \end{cases} \tag{39}$$

Two different proofs [34-36] of this Theorem based on the M.TH. and G.TH..

The analogical situation is for an investigation the delicate ϵ'/ϵ problem. Usual methods of the experimental determination of ϵ'/ϵ based [2,37,38] on the main statements of the LOY theory for 2π decay modes for K^0 experiments and also for corresponding factory correlation experiments. It was derived [35], in paricular, that the exact HS QT predicts additional term to $Re(\epsilon'/\epsilon)$ of the order $2 \cdot 10^{-4}$. This fact is essential, because the accuracy of recent experimental works [37,38] is close to this order.

10. The results of the exact theory beyond the LOY theory are very essential also for possibility, by investigation of K^0, $\bar{K}^0$ dynamics, to test possible violation of the standard quantum dynamics, connected with effects of the quantum gravity [7–11]. First of all, in [7–9, 11] also was used the W.W. approximation and corresponding theoretical statement of the existness such superpositions K_S, K_L of K^0, $\bar{K}^0$, which do not regenerate to each other in the vacuum and have simple exponential decay laws. Of course, the exact dynamics of the nonstandard quantum dynamics for $K^0(t)$, $\bar{K}^0(t)$ and the exact dynamics of the standard QT are in general different. But some predictions of the exact QT dynamics for K^0, $\bar{K}^0$ look as some (the main parts of the specific effects from [7–9, 11]) predictions of the nonstandard quantum dynamics in the W.W. approximation. I shall not go here in detail investigation of this problem [34,39], but only indicate one of such effect. In [9] it was pointed on the base of results from [32], that the full time dependence of the decay into identical states, for example, to (π^+, π^-), (π^+, π^-) in corresponding correlation factory experiment is independent of the CP-violation parameters. This is easy to see from the LOY prediction (32). At the same time in [9] it was pointed that when we allow for a departure from standard quantum mechanics, this is no longer true. But, as follows from the exact theory, the standard HS quantum dynamics also predicts (see (33)) such new effect. It is interesting to point out, from another side, that the exact HS QT dynamics predicts for identical decay channels $f_1 = f_2$ at equal times $t_1 = t_2$ zero correlation amplitude (see (33)). So the experimental indication of nonzero effect for this correlation will [10] indicate the violation of the standard quantum mechanics.

11. The cases of $B^0 - \bar{B}^0$ and $D^0 - \bar{D}^0$ mesons are different from the usual case of $K^0 - \bar{K}^0$ mesons, because theoretical predictions states that the ratio q/p for $B^0 - \bar{B}^0$ and $D^0 - \bar{D}^0$ mesons is with good accuracy such

$$|q/p| = 1, q/p = exp(i\Phi) \tag{40}$$

but in principle $|q/p| \neq 1$. The last comment is essential for the truth of the M.TH for $B^0 - \bar{B}^0$ and $D^0 - \bar{D}^0$ mesons. From another side from (40) follows that the life times of B_S and B_L are with good accuracy the same $\Gamma_S = \Gamma_L = \Gamma_B$. The same is true for D_S and D_L-in our notations $\Gamma_S = \Gamma_L = \Gamma_D$. From this follows that for $B^0 - \bar{B}^0$ and $D^0 - \bar{D}^0$ mesons do not exist analogs of usual classical three CP-violation effects, which was derived for $K^0 - \bar{K}^0$ mesons. For investigation of the CP-violation effects for $B^0 - \bar{B}^0$ and $D^0 - \bar{D}^0$ mesons is essential to investigate corresponding correlations in factory experiments. For future asymmetric factories it will be possible to investigate the time dependence correlation experiments. For such experiments are true corresponding analogs of Eqs. (32), (33). For the symmetric B factories (like in Cornell) possible to investigate only the time integrated results of the type

$$R_B = \frac{\int_0^\infty |p_{\bar{B}^0 B^0}(t)|^2 dt}{\int_0^\infty |p_{B^0 B^0}(t)|^2 dt} \tag{41}$$

and

$$A_T(B) = \frac{\int_0^\infty [|p_{B^0 \bar{B}^0}(t)|^2 - |p_{\bar{B}^0 B^0}(t)|^2] dt}{\int_0^\infty [|p_{B^0 \bar{B}^0}(t)|^2 + |p_{\bar{B}^0 B^0}(t)|^2] dt} \tag{42}$$

Within usual approximate LOY theory possible to obtain such known results:

$$R_B^{LOY} = \frac{x_B^2}{2 + x_B^2} \tag{43}$$

where $x_B = (\Delta m / 2\Gamma_B) \simeq 0.73$ is the mixing parameter, and

$$A_T^{LOY}(B) = |p|^2 - |q|^2 \simeq 0 \tag{44}$$

But in the exact theory beyond the approximate LOY theory we obtain after long but simple evaluations (on the base of corresponding expressions for $p_{B^0\bar{B}^0}(t)$ and $p_{\bar{B}^0B^0}(t)$, which are analogical to (36a,b)) such results:

$$R_B^{exact} = R_B^{LOY}[1 + 2Rea - 2(Ima)/x_B] \tag{43a}$$

and

$$A_T^{exact}(B) = 2[Rea + (Ima)/x_B] \tag{44a}$$

where parameter a is

$$\begin{cases} a = (i\Gamma_B/(\Delta m + 2i\Gamma_B)) \\ \sum_f [|A_f(B^0 \to f)|^2 - |\bar{A}_f(\bar{B}^0 \to f)|^2 \\ +exp(i\Phi)A_f^*(B^0 \to f)\bar{A}_f(\bar{B}^0 \to f) \\ -exp(-i\Phi) - exp(-i\Phi)A_f(\bar{B}^0 \to f)\bar{A}_f^*(\bar{B}^0 \to f)] \end{cases} \tag{45}$$

The magnitude of a depends from the magnitude of the CP-violation, and from the mass overlapping, which gives the amlification factor. The more interesting result is in Eq. (44a), because within the usually used approximate LOY theory it is *impossible*, as follows from Eq. (44)($A_T^{LOY}(B) \simeq 0$), to investigate by symmetric B factories the CP-violation effect. For the case of $D^0 - \bar{D}^0$ mesons the corresponding result, analogical to (44a), is specially interesting, because the mixing parameter x_D is less than 10^{-2}. In a separate publication I shall present more details for the specific cases of $B^0 - \bar{B}^0$ and $D^0 - \bar{D}^0$ mesons.

12. From the new theoretical results of the exact HS QT follow some proposals for CP LEAR and factory experiments. Such future experiments could give possibility to test what formulation (standard Hilbert Space or Rigged Hilbert Space) is more adequate to the physical reality.

By CP LEAR and factory experiments possible to test direct unconditional test (9) of the CPT-invariance. It is also very interesting to test the new CP-violation effect (25). The experimental investigation of this effect will give also direct tests of the T-noninvariance and the Superposition Principle. It is also interesting to see by CP LEAR that the interference terms in the 2π decay modes for $K^0(t)$ and $\bar{K}^0(t)$ are not different only in sign. It is also interesting to test by CP LEAR and by factory correlations new effects [34,35,40] in the time dependence of the charge asymmetry in the semileptonic decay channels for $K^0(t)$ and $\bar{K}^0(t)$. By factory experiments possible to test quantum Tsirelson's inequalities [12], which could give indication for very general violation of the first principles of standard QT. The detail investigations of new proposals for CP LEAR and factory experiments [41] will be published in a separate publication.

REFERENCES

1. J. H. Cristensen, J. W. Cronin, V. L. Fitch and R. Turlay, Phys. Rev. Lett., v.13, 138 (1964).
2. The DAϕNE PHYSICS HANDBOOK, L. Maiani, G. Pancheri and N. Paver, eds. (INFN, Frascati, 1992).

2a. E. A. Paschos, "CP Violation: Prsent and Future," Preprint Fermilab, FERMILAB-Conf-96/045-T, Batavia, USA, 1996.

3. P. K. Kabir, Phys. Rev., D2, 540 (1970).

3a. P. K. Kabir and A. Pilaftsis, Phys. Rev., A53, 66 (1996).

4. G. V. Dass, Phys. Rev., D45, 980 (1992).
5. Leonid A. Khalfin, "On the Test of Superposition," preprint Research Institute for Theoretical Physics, The University of Helsinki, HU-TFT-92, Helsinki, March 1992.
6. Leonid A. Khalfin, - in Abstracts of reports on the XIX International Colloquium on Group Theoretical Methods in Physics, v. 1, 25 (1992), Salamanka (Spain).
7. J. Ellis, J. S. Hagelin, D.N.Nanopouls and M. Srednicki, Nucl. Phys., B241, 381 (1984).
8. J. Ellis, N. E. Mavromatos and D. N. Nanopoulos, Phys. Lett., B293, 142 (1992).
9. Patrick Huet and Michael E. Peskin, "Violaton of CPT and Quantum Mechanics in the K^0 - $\bar{K}^0$ System," preprint SLAC-PUB-6454, March 1994; Nucl. Phys.,B434, 3 (1995).
10. P. Eberhard, "Tests of Quantum Mechanics at a ϕ- factory," report at EURODAϕNE Collaboration Meeting, Frascati, April 19-22, 1994.
11. N. Mavromatos, "Violations of Quantum Mechanics and CPT from Plankian Scale Physics at DAϕNE," report at EURODAϕNE Collaboration Meeting, Frascati, April 19-22, 1994.
12. Leonid A. Khalfin and Boris S. Tsirelson, Found. Phys., v.22, 879 (1992).
13. T. D. Lee, R. Ohme, C. N. Yang, Phys. Rev., v. 106, 340 (1957)
14. L. A. Khalfin, "Theory of $K^0 - \bar{K}^0$, $D^0 - \bar{D}^0$, $B^0 - \bar{B}^0$ mesons beyond Weisskopf- Wigner approximation and the CP-violation problem," preprint LOMI, P-4-80, Leningrad, 1980.
15. L. A. Khalfin, - in Proceedings of Seminar "Group Theoretical Methods in Physics," M. Markov ed., v.2, 608, "Nauka," M., 1986.
16. L. A. Khalfin, "New Results on the CP-violation Problem," preprint CPT, The University of Texas at Austin, DOE- ER 40200-211, Austin, February 1990.
17. L. A. Khalfin, "A New CP-violation Effect and a New Possibility for Investigation of K_S, K_L (K^0, $\bar{K}^0$) Decay Modes," preprint CPT, The University of Texas at Austin, DOE- ER 40200-246, Austin, March 1991.
18. Leonid A.Khalfin, "CP-violation Problem Beyond Standard Lee- Oehme- Yang Theory," June 1994, submitted to "The DAFNE Physics Handbook"
19. C. B. Chiu and E. C. G. Sudarshan, Phys. Rev., D42, 3712 (1990).
20. E. C. G. Sudarshan and C. B. Chiu, Phys. Rev., D47, 2602 (1993).
21. Ya. Azimov, JETPh Lett., v. 58, 159 (1993).
22. A. Bohm, "Quantum Mechanics," 3rd Edition, Springer, NY (1994); A. Bohm, I. Antoniou, P. Kielanowski, J. Math. Phys., v.36,2593 (1995).
23. L. A. Khalfin, DAN USSR, v. 115, 277 (1957): JETPh, v. 32, 1371 (1958).
24. L. A. Khalfin, Uspekhi Physicheskikh Nauk, v.166, N6, 688 (1996).
25. L. A. Khalfin, report on scientific session the Nuclear Physics Department Academy of Sciences USSR, 1968; "Investigations of the quantum theory of unstable elementary particles," Doctor of Sciences dissertation, FIAN (1968)- LTF JINR (1972).
26. H. Lipkin, unpublished, 1964.
27. CP LEAR Collaboration, R. Adler et al., Phys. Lett., B286, 180 (1992).

28. J. S. Bell, J. Steinberger, Proceedings of the Oxford International Conference on Elementary Particles, 1965.
29. L. A. Khalfin, JETPh Lett., v. 25, 349 (1972).
30. Leonid A. Khalfin, "An Exact Theory of the CP-violation Problem within CPT-noninvariant Quantum Theory," unpublished, 1994.
31. P. Pavlopoulos, "Measurements of CP and T VIolation Parameters in the Neutral Kaon System at CP LEAR"-in "Workshop on Physics and Detectors for DAFNE'95," Frascati Physics Series, v.IV, eds. R. Baldini, F. Bossi, G. Capon, G. Pancheri,55 (1995); R. LeGac, "Study of CP, T and CPT in the Neutral K System"-report on Workshop on K Physics, Orsay, May 1996.
32. C. D. Buchanan, R. Cousin, C. O. Dib, R. D. Peccei and J. Quackenbush, Phys. Rev., D45, 4088 (1992).
33. L. Khalfin, "CP-violation and CPT-invariant Tests beyond Standard Lee–Ohme–Yang Theory," report at EURODAϕNE Collaboration Meeting, Frascati, April 19-22, 1994- in LNF-94/033 (IR), 249, 7 giugno 1994.
34. Leonid A.Khalfin "CP-violation Problem Beyond Approximate Lee- Oehme- Yang Theory," report on Workshop on Physics and Detectors for DAFNE'95, April 1995.
35. Leonid A.Khalfin, "Unconditional Tests of Discrete Symmetries by K Mesons Beyond the Approximate Lee- Oehme- Yang Theory," report on Workshop on K Physics, Orsay, May 1996 (to be published in Proceedings).
36. Leonid A.Khalfin, "On the CPT-invariant Theory of CP-violation," PDMI PREPRINT-3/1995.
37. E371; L. K. Gibbons et al., Phys. Rev. Lett., v. 70, 1199 and 1203 (1993).
38. NA31; G. D. Barr et al., Phys. Lett., B317, 233 (1993).
39. Leonid A.Khalfin, "The Exact Theory of the CP-violation Problem and Violation of Quantum Mechanics," 1994 (unpublished).
40. Leonid A.Khalfin, "On Charge Asymmetry in Semileptonic Decay Channels in the Exact Theory of the CP-violation Problem," 1994 (unpublished).
41. Leonid A.Khalfin, "On the decay and regeneration amplitudes and corresponding probabilities for $K^0 - \bar{K}^0$ mesons from correlation experiments on ϕ factories," PDMI PREPRINT-4/1995.