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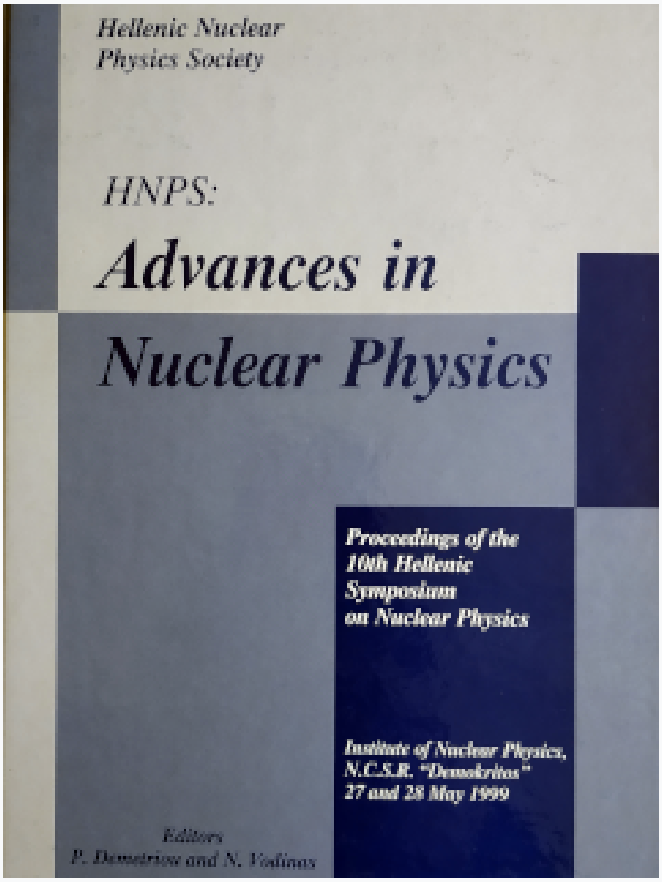

Theory of Time Asymmetry and Strangeness Oscillation of K°

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Theory of Time Asymmetry and Strangeness Oscillation of K^0

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Abstract

The predicted value for the T-asymmetry, A_T^{theory}, of the neutral kaons strangeness oscillation in the framework of the chronotopological stochastic quantum field theory is $A_T^{theory} = 6.6\times10^{-3}$ and the corresponding diameter of the interaction proper-time neighborhood, is $\delta(\tau_\lambda) = 2.382 \times 10^{-27}$ s. The antiproton energy in the reaction for the kaon production is $E_{\overline{p}} = 200\ MeV$. The time evolution operator, $C(\mathcal{T}_{\Lambda_\kappa})$, acting on the state vector gives two contributions, one unitary and one decoherent. A_T^{theory} as a function of $E_{\overline{p}}$ shows that $\overline{K}^0$- decays (antimatter) were more abundant than matter decays at higher temperatures of the universe. $C(\mathcal{T}_{\Lambda_\kappa})$ appears in two disjoint subsets of denumerably many forms, unitary and non-measure preserving. The evolution operator of the standard quantum field theory is identical to the zeroth-order element of the unitary subset. The set of evolution paths $S_{chronotop.}$, produced by $C(\mathcal{T}_{\Lambda_\kappa})$ is denumerable (quantized) in contradistiction to the set, $S_{Feynman}$, of trajectories in the path integral which is continuous. The value measured recently by the CPLEAR-Collaboration at CERN is $\langle A_T^{Exper.}\rangle = (6.6 \pm 1.3) \times 10^{-3}$. The agreement with the predicted value is excellent.

1 Introduction

The time-reversal invariance of the fundamental equations of physics and the irreversibility of the overwhelming majority of physical phenomena represented one of the most complicated puzzles in the 20-th century physics. Classical thermodynamics as well as elementary particle physics and quantum field theory were the first physics areas in which time-symmetry was extensively discussed by Dirac [1], Halmos [2], Tolman [3], Courdin [6], Wheeler [7], Kabir [9, 12], Casella [11], Glashow et al.[12].

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Time-symmetry always was and still is considered today as a *sine qua non* property of the equations of physics. This was definitely established by the Noether theorem [13]. The reason, however, why this property is so important is understood in a different ways in standard QFT and in chronotopology. While the fundamental equations of physics must exhibit time symmetry, not all phenomena in nature are symmetric against the time-reversal operation, $t \to t' = -t$.

In discussing a given physical phenomenon using chronotopology time has to be defined either *as a positive* variable or *as a negative* variable. Changing time sign during the study of given phenomenon may lead to the creation of paradoxes.

The first hint that time-symmetry might not be a generally valid physical property became was announced by Lee and Wu [8] in conjunction with the parity violation β-decay in weak interactions. The first experimental evidence for the T-non-invariance of elementary particle processes came from the decay of K^0 discovered by Christenson et al. [4] and was analyzed by Kabir [9,12]. Time-quantization was deduced by Syros [14] from Liouville's theorem and conserves time-symmetry under certain conditions. Also, time-asymmetry was also discovered by Nicolis and Prigogine [15] in theories of self-organizing systems and by Syros with non-Hermitian Hamiltonians [16]. The Hermitian Hamiltonian, however, is not of general physical interest in quantum field theories.

A new method for obtaining time-asymmetric evolution in coexistence with the unitary sector in the framework of quantum field theory was obtained by Syros [17,18] by combining the theory of generalized random and infinitely divisible fields studied by Gel'fand and Vilenkin [5], on the basis of a new time topology, the chronotopology. Chronotopology generated for the first time the quantum logical alternative "*either unitarity or non-measure-preservation*". Non-measure-preserving transformations are studied by Halmos in ergodic theory [2].

Hence, chronotopology provided the since long desired time asymmetric evolution description in Hermitian QFT . The new theory is applied in the present work to describe the CPLEAR-experiment. It has been proved by Syros [27] that methods using an imaginary time variable ($t \to t' = -it$) are equivalent to a subclass of theories using *non-self-adjoint Hamiltonians* ($H \neq H^+$). These theories not compatible with chronotopology and, hence, are not discussed here.

Since recently there also exist theories developed by Ellis et al. [20,21] and by Huet et al. [22] which successfully describe decoherent evolution leading to T-asymmetry. These are developed on quite different mahtematical and physical principles and a discussion of them in comparison with chronotopology would be of great interest to the appreciation of their relationship.

The purpose of the present article is to give a consistent theoretical treatment of the T-asymmetry observed in the strangeness oscillation of the $K^0 - \overline{K}^0$system and measured recently by the CPLEAR-Collaboration, Angelopoulos et al. [28].

One of the main features of chronotopology is that, on the one hand, it is based exclusively on a real time variable [2] and, on the other hand, supports the established Hermitian field theories. In addition, the basic principles of quantum theory are respected. Chronotopology preserves, also, the CPT theorem as well as the Noether theorem on account of the *quantitave equivalence* between R^1 and the interaction proper-time neighborhood, τ_λ, as stated by Alexandroff [29].

It is pointed out that in order to open a closed system of interacting particles no additional terms are needed to the well-established equations of QFT. All the above requirements are met by the non-measure-preserving evolution operator.

The systematic investigation into the T- reversal invariance and the T-asymmetry in nature led to the recognition that the time topology was the root of the issue. The proofs of the theory required for establishing the theory on which are based the results presented here can be found in ref. [23] by Syros and Schulz-Mirbach and in subsequent papers.

It is important to point out that:

(i) The action of the general evolution operator, $C(\mathcal{T}_{\Lambda_\kappa})$, on a state vector, $\Psi(t)$, is neither only coherent nor only decoherent; it is both. This is seen from the presence of real and imaginary terms in the exponentials of the transition amplitudes in eqs.(10,11) below [3] .

(ii) The expression of A_T^{Theory} depends on the masses of the involved particles, on the antiproton energy and on the constants $\hbar$and c, the velocity of light. One parameter is the interaction proper-time neighborhood diameter,$\delta(\tau_\lambda)$. The particle rest masses were taken from [19].

$C(\mathcal{T}_{\Lambda_\kappa})$ whose action leads to the expression for A_T^{Theory} combines the hitherto impossible to explain irreversibility of the natural phenomena with the unitary evolution in the framework of the Schroedinger theory.

By Bohr quantizing the field action integral

$$\int_{\overline{M}^4_{\Lambda_\kappa}} dx^4 \ell(\varphi(x), \partial_\mu \varphi(x)) = \hbar\Lambda(j,\sigma), \text{Bohr quantization}, \qquad (1)$$

[2] Solutions of the Einstein field equations corresponding to imaginary time variable does not give gravitational fields (Landau and Lifchitz [31]). Also, theories related to general relativity and based on imaginary time become questinable after the recent discovery of the extremely strong radiation emitted by black holes.

[3] A_T^{Theory} $(E_{\overline{p}})$ takes values in [0,1) for $E_{\overline{p}}$ in [0,1.2] PeV.

where

$$\Lambda(j,\sigma) = \begin{matrix} j+1/2, \sigma = 1, \text{Fermi}-\text{Dirac} \\ \\ j, \quad \sigma = -1, \text{Bose}-\text{Einstein} \end{matrix} \tag{2}$$

the double effect is implemented by means of the evolution operator

$$C(\mathcal{T}_{\Lambda_\kappa}) = \exp\left\langle \begin{matrix} \frac{-i\cos\Lambda(j,\sigma)}{\hbar}\int_{\overline{M}^4_{\Lambda_\kappa}} dx^4 h(\varphi(x),\partial_\mu\varphi(x)) + i\Lambda(j,\sigma)\cos\Lambda(j,\sigma)+ \\ \frac{-\sin\Lambda(j,\sigma)}{\hbar}\int_{\overline{M}^4_{\Lambda_\kappa}} dx^4 h(\varphi(x),\partial_\mu\varphi(x)) + \Lambda(j,\sigma)\sin\Lambda(j,\sigma) \end{matrix}\right\rangle \tag{3}$$

it yields either unitarity or decoherence, i.e., eq.(3) breaks down to the two disjoint operators:

(i) Non measure preserving (nmp)

$$U_{nmp}(\mathcal{T}_{\Lambda_\kappa}) = \exp\left\langle \frac{-\sin\Lambda(j,\sigma)}{\hbar}\int_{\overline{M}^4_{\Lambda_\kappa}} dx^4 dx^4 h(\varphi(x),\partial_\mu\varphi(x)) + \Lambda(j,\sigma)\sin\Lambda(j,\sigma)\right\rangle \tag{4}$$

or

(ii) Unitary (u):

$$U_u(\mathcal{T}_{\Lambda_\kappa}) = \exp\left\langle \frac{-i\cos\Lambda(j,\sigma)}{\hbar}\int_{\overline{M}^4_{\Lambda_\kappa}} dx^4 dx^4 h(\varphi(x),\partial_\mu\varphi(x)) + i\Lambda(j,\sigma)\cos\Lambda(j,\sigma)\right\rangle. \tag{5}$$

Eqs. (4, 5) show that the fundamental QFT equations are indeed time-symmetric, but certain of their solutions may exhibit T-asymmetry[4].

In the above equations $\ell(\varphi(x),\partial_\mu\varphi(x))$ is the Lagrangian field density[5] and $h(\varphi(x),\partial_\mu\varphi(x))$ the Hamiltonian field density

$$h(\varphi(x),\partial_\mu\varphi(x)) = \partial_0\varphi(x)\pi(x) - \ell(\varphi(x),\partial_\mu\varphi(x)). \tag{6}$$

[4] The separation of coherent and decoherent actions of $C(\mathcal{T}_{\Lambda_\kappa})$ is implied by the Bohr quantization.

[5] $\ell(\varphi(\S),\partial_\mu\varphi(x))$ is formally unrestricted provided it fulfills the required symmetry conditions.

2 Analysis of the T-asymmetry

After the derivation of the T-symmetry violating evolution operator, $U_{nmp}(\mathcal{T}_{\Lambda_\kappa})$, it was realized that the theoretical description of the CP-symmetry violation in the decay of the $K^0 - \overline{K}^0$system was within reach by:

(a) preserving hermiticity of the Hamiltonian,

(b) preserving the reality of the time variable in quantum mechanics and

(c) respecting the CPT theorem.

The existence of T-symmetry violation by the $K^0 - \overline{K}^0$ system becomes quite clear from the validity of the CPT-theorem.

The CPLEAR- Collaboration carried out the experiment and they found a T-symmentry violation by the strageness-oscillation of the neutral kaons. The expression for the experimental T-asymmetry is given by the ratio

$$A_T^{\text{exp.}}(\tau) = \frac{\eta N(\overline{K}^0_{t=0} \to e^+\pi^-\nu_{t=0}) - \xi N(K^0_{t=0} \to e^-\pi^+\overline{\nu}_{t=0})}{\eta N(\overline{K}^0_{t=0} \to e^+\pi^-\nu_{t=0}) + \xi N(K^0_{t=0} \to e^-\pi^+\overline{\nu}_{t=0})}. \tag{7}$$

In eq.(7) N is the number of the events in the parenthesis during the time $0 \leq t \leq \tau$ and (η, ξ) are normalization factors explained by Angelopoulos et al. [28].

The Hamiltonian density of the fields involved in the process consists of the sum of the Hamiltonian densities of the fields of the particles e, ν, K^0, π, which are (Ψ, ψ, Φ, ϕ) respectively and whose quanta are on the one hand the leptons and on the other hand the mesons. The dynamics of the symmetry violations discussed in this paper are determined by the Hamiltonian densities of the interacting fields

$$\begin{aligned}
h_e(x) &= (-i\hbar\Psi_e^+(x)\overrightarrow{\alpha}\cdot(\nabla - e\overrightarrow{A}(x))\Psi_e(x) + m_{0e}c^2\Psi_e^+(x)\beta\Psi_e(x),\\
h_\nu(x) &= (-i\hbar\Psi_\nu^+(x)\overrightarrow{\alpha}\cdot\nabla\Psi_\nu(x) + m_{0\nu}c^2\Psi_\nu^+(x)\beta\Psi_\nu(x),\\
h_{K^0}(x) &= -(\tfrac{\hbar^2}{2m_\pi}\partial_\lambda\Phi_{K^0}(x)\partial^\lambda\Phi_{K^0}(x)) + \pi_{K^0}(x)\partial_0\Phi_{K^0}(x) + m_{K^0}c^2\Phi_{K^0}(x)^2,\\
h_\pi(x) &= -(\tfrac{\hbar^2}{2m_\pi}\partial_\lambda\Phi_\pi(x)\partial^\lambda\Phi_\pi(x)) + \pi_\pi(x)\partial_0\Phi_\pi(x) + m_\pi c^2\Phi_\pi(x)^2
\end{aligned} \tag{8}$$

for $x \in \overline{M}^4_{\Lambda_\kappa}$.

The total Hamiltonian, h, is

$$h = h_e + h_\nu + h_{K^0} + h_\pi. \tag{9}$$

The predicted T-asymmetry, $A_T^{theory}(\delta(\tau_\lambda))$, was calculated from the matrix elements using eq.(9) for the transition amplitudes $K^0 \rightarrow e^-\pi^+\overline{\nu}$ and $\overline{K}^0 \rightarrow e^+\pi^-\nu$ between the states $\langle P|C^+(\mathcal{T}_{\Lambda_\kappa})$ and $C(\mathcal{T}_{\Lambda_\kappa})|P\rangle$, where $|P\rangle$ represents the respective particle state.

More specifically, the transition matrix elements are given by the expressions:

$$\langle e^+\pi^-\nu|C^+(\mathcal{T}_{\Lambda_\kappa})C^+(\mathcal{T}_{\Lambda_\kappa})||\overline{K}^0\rangle = \exp[\frac{iE_{\overline{K}^0}\delta(\tau_\lambda)}{\hbar} + i\pi \times n_{\overline{K}^0} + \frac{(-E_{e^+} - iE_{\pi^-} + E_\nu)\delta(\tau_\lambda)}{\hbar} + \pi \times (n_{e^+} + in_{\pi^-} + n_\nu)] \tag{10}$$

and

$$\langle e^-\pi^+\overline{\nu}|C^+(\mathcal{T}_{\Lambda_\kappa})C^+(\mathcal{T}_{\Lambda_\kappa})||K^0\rangle = \exp[-\frac{iE_{K^0}\delta(\tau_\lambda)}{\hbar} + i\pi \times n_{K^0} + \frac{(-E_{e^-} + iE_{\pi^+} - E_{\overline{\nu}})\delta(\tau_\lambda)}{\hbar} + \pi \times (n_{e^-} + in_{\pi^+} + n_{\overline{\nu}})] \tag{11}$$

Since energy conservation holds, the available energy is partitioned to the particles emitted from the disintegration of the mesons K^0or $\overline{K}^0$. The respective transition matrix elements are calculated by letting the chronotopological evolution operator, eq.(3), act on the respective states as in eqs.(10,11). One gets, therefore, for the transition ratio the expression

$$\begin{aligned} A_T^{Theory} = |\{&exp[\frac{iE_{\overline{K}^0}\delta(\tau_\lambda)}{\hbar} + i\pi \times n_{\overline{K}^0} + \frac{(E_{e^+} - iE_{\pi^-} - E_\nu)\delta(\tau_\lambda)}{\hbar} + \pi \times (n_{e^+} + in_{\pi^-} + n_\nu)] - \\ &exp[-\frac{iE_{K^0}\delta(\tau_\lambda)}{\hbar} + i\pi \times n_{K^0} + \frac{(-E_{e^-} + iE_{\pi^+} - E_{\overline{\nu}})\delta(\tau_\lambda)}{\hbar} + \pi \times (n_{e^-} + in_{\pi^+} + n_{\overline{\nu}})]\}/ \\ \{&exp[\frac{iE_{\overline{K}^0}\delta(\tau_\lambda)}{\hbar} + i\pi \times n_{\overline{K}^0} + \frac{(E_{e^+} - iE_{\pi^-} - E_\nu)\delta(\tau_\lambda)}{\hbar} + \pi \times (n_{e^+} + in_{\pi^-} + n_\nu)] + \\ &exp[-\frac{iE_{K^0}\delta(\tau_\lambda)}{\hbar} + i\pi \times n_{K^0} + \frac{(-E_{e^-} + iE_{\pi^+} - E_{\overline{\nu}})\delta(\tau_\lambda)}{\hbar} + \pi \times (n_{e^-} + in_{\pi^+} + n_{\overline{\nu}})]\}|. \end{aligned} \tag{12}$$

The particle energies in eq.(12) are functions of the particles rest masses and of the laboratory energy of the antiprotons in the CPLEAR experiment and are given here in MeV:

$$E_{\overline{p}} = 200$$

$$E_{tot.} = E_{\overline{p}} + 2m_p - m_{K^\pm} - m_{K^0} - m_{\pi^\pm}$$

$$E_{K^0} = (E_{\overline{p}} + 2m_p - m_{K^\pm} - m_{K^0} - m_{\pi^\pm}) \times m_{K^0}/(m_{K^\pm} + m_{K^0} + m_{\pi^\pm}) + m_{K^0}$$

$$E_{\pi^\pm} = (((E_{\overline{p}} + 2m_p - m_{K^\pm} - m_{K^0} - m_{\pi^\pm}) \times m_{K^0}/(m_{K^\pm} + m_{K^0} + m_{\pi^\pm}) + m_{K^0}) \times m_{\pi^\pm}/(m_{\pi^\pm} + m_{e^\pm} + m_\nu) + m_{\pi^\pm})$$

$$E_{e^\pm} = (((E_{\overline{p}} + 2m_p - m_{K^\pm} - m_{K^0} - m_{\pi^\pm}) \times m_{K^0}/(m_{K^\pm} + m_{K^0} + m_{\pi^\pm}) + m_{K^0}) \times m_{e^\pm}/(m_{\pi^\pm} + m_{e^\pm} + m_\nu) + m_{e^\pm})$$

$$E_\nu = (((E_{\overline{p}} + 2m_p - m_{K^\pm} - m_{K^0} - m_{\pi^\pm}) \times m_{K^0}/(m_{K^\pm} + m_{K^0} + m_{\pi^\pm}) + m_{K^0}) \times m_\nu/(m_{\pi^\pm} + m_{e^\pm} + m_\nu) + m_\nu).$$

E_{tot}represents the total energy available to the process studied and increase with increasing $E_{\overline{p}}$.

The predicted value for the measured T-asymmetry ratio is ploted in Fig. 1 as a function of the diameter, $\delta(\tau_\lambda)$, of the interaction proper-time neighborhood, τ_λ. The intersection of the straight line segment with the time-axis determines the value of . $\delta(\tau_\lambda)$ which corresponds to the observed value of A_T^{Theory}.

It is expected that the same method combined with the appropriate chronotopological quantum numbers will predict the T-asymmetry for every meson-antimeson oscillating system, e.g., the B-mesons.

The following data were used in the numerical evaluation of the function A_T^{Theory} in the Laboratory system of reference:

$\hbar = 1.0544 \times 10^{-34} Js$

$E_{\overline{p}} = 200 Mev$

Diameter of the interaction proper-time neighborhood: $\delta(\tau_\lambda) = 2.382 \times 10^{-27} s$

Masses in MeV:

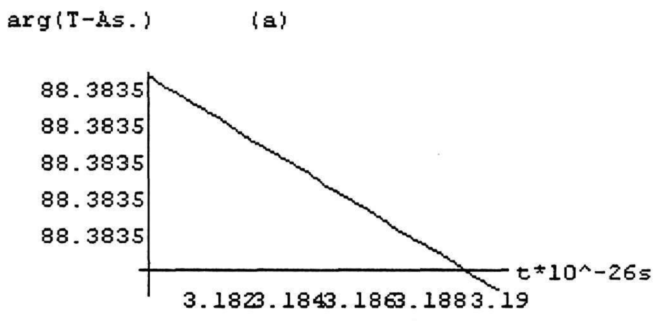
Protons: m_p =938.3,

Mesons: $m_{K^0} = 497.67$, $m_{K^\pm} = 493.65$, $\pi^\pm = 139.57$,

Leptons: $e^\pm = 0.511$, $\nu, \overline{\nu} = 0.000073$.

Quantum numbers

Leptons: $n_{e^-}, n_\nu = \frac{1}{2}$, $n_{e^+}, n_{\overline{\nu}} = \frac{-3}{2}$



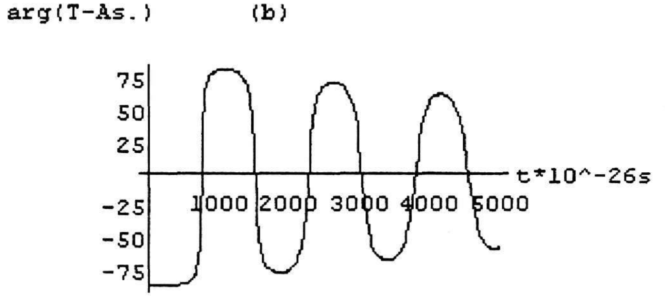


Fig. 1. A plot of the T-asymmetry ratio as a function of the interaction proper-time neighborhood diameter. The intersection of the straight line segment with the time-axis gives just the value t = $3.1865*10^{-26}$s cor- responding to the observed T-asymmetry (a). The ratio in a larger time interval is shown in (b).*)

Mesons: $n_{K^0}, n_{\pi^+} = 1$, $n_{\overline{K}^0}, n_{\pi^-} = -1$.

With the help of the above data [19] one finds from eq. (12) that the back transformation of the antikaon into kaon,

$K^0 \leftarrow \overline{K}^0$, proceeds with a smaller probability than the direct transformation, $K^0 \rightarrow \overline{K}^0$.

The experimental and the predicted absolute ratios are:

$$A_T^{Theory} = 6.6 \times 10^{-3} \text{and} \langle A_T^{\text{Experim.}} \rangle = (6.6 \pm 1.3) \times 10^{-3}.$$

The weaker transforming $K^0 \leftarrow \overline{K}^0$ makes the abundance of $\overline{K}^0$ higher and, hence, more of them ($\overline{K}^0$) are available to decay semi-leptonically at the end of its life-time.

The reason, therefore, for the T-asymmetry in the framework of chronotopology appears to be not the time-inversion - which does not occur at all - but rather the quantum numbers, $\Lambda(j, \sigma)$, of the particles involved in the transformation process under observation. The quantum numbers, $\Lambda(j, \sigma)$, are those following from the Bohr quantization of the field-action integral and they are positive or negative integers or half-odd integers. They determine the sign in front of the particle energies in the exponentials of eqs.(4, 5) and of the respective transition matrix elements, eqs.(10, 11). These signs determine the difference of the transition amplitudes.

3 The "matter to antimatter" ratio

Of particular interest is A_T^{Theory} as a function of the energy (Figs. 2). The energies of the particles correspond to the temperature of the universe which determines the kind of elementary particle reactions which are possible.

It follows from eq. (12) that at high temperatures the matrix element, $\langle e^-\pi^+\overline{\nu}|C^+(\mathcal{T}_{\Lambda_\kappa})C^+(\mathcal{T}_{\Lambda_\kappa})|K^0\rangle$, for the transition $K^0 \rightarrow e^-\pi^+\overline{\nu}$ vanishes as teperature becomes very high. In contrast, the matrix element $e^+\pi^-\nu|C^+(\mathcal{T}_{\Lambda_\kappa})C^+(\mathcal{T}_{\Lambda_\kappa})||\overline{K}^0$ for the transition $\overline{K}^0 \rightarrow e^+\pi^-\nu$ takes large values. This may be understood by assuming that the abundance of K^0 mesons is lower than that of $\overline{K}^0$. As $\overline{K}^0$ is characterized as antimatter - as discussed by Jacob [30] - this implies an asymptotic absence of matter in the form of K^0 for macroscopic time $t \rightarrow 0$.

If similar is the case also with the other heavy matter-particles it would imply the unexpected event that antimatter prevailed in earlier ages of the universe and would explain why matter is accumulated today in the universe. This would, then, be the reason for which antimatter is scarcely observed today. In this case one should expect that with cooling of the universe advancing all antiparticles will, according to the present theory, disappear.

Moreover, by assuming a constant cooling rate one one obtains an independent way to estimate the age or, conversely, of the expansion velocity of the universe.

Hence, the matrix elements can be considered as dependent on the temperature of the universe. This proves that the ratio "matter to antimater" is not constant of the universe.

4 The subatomic world looks exactly the same with either sign of time

The opinion still exists with some researchers that time might be reverted. In chronotopology one may define time as either positive or as negative and keep the definition

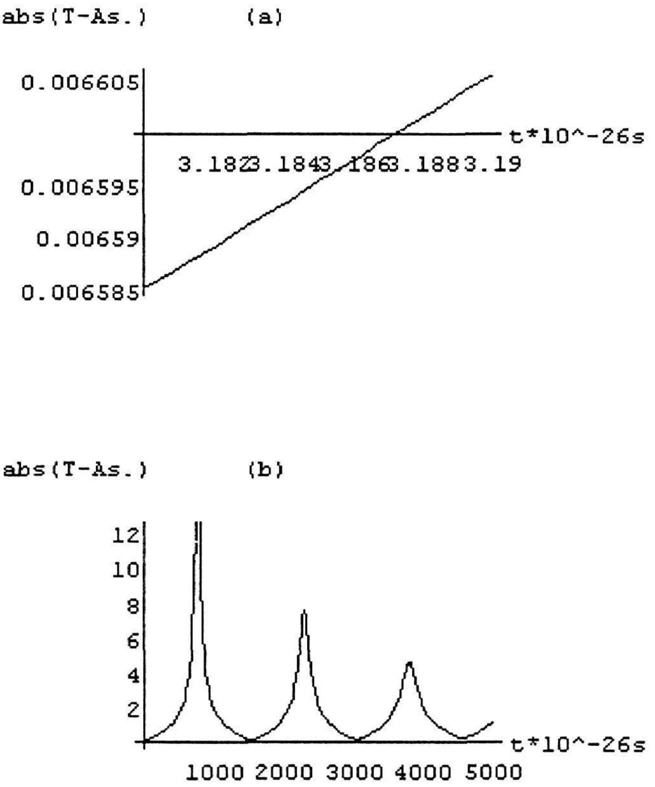


Fig. 2. The phase angle of the T-Asymmetry ratio in the semileptonic decay of the Ko-Kobar system according to eq.(12) as a function of the inter- action proper-time neighborhood diameter. In a small time range there is practically no variation (a), while in a larger time interval it shows a characteristic form (b)

unchanged within a given theory. The Noether theorem expresses just this possibility to define time as only positive or as only negative. The sub-atomic world does not take notice of our changing the definition of any mathematical parameter whatsoever. Strange things may happen if the sign of the time variable is changed while studying a problem in the framework of any given theory. Of related character is, for example, the puzzle of the "advanced waves" in electromagnetism.

This stresses the importance of the time-reversal properties of physical theories and of the Noether theorem in QFT. According to chronotopology, sets of solutions do not behave like single solutions of equations that are time-symmetric.

Something, however, does not look the same after time-reversal. This is, certainly, in no case the subatomic world; it is the way we describe it.

Stochastic QFT is the appropriate theory to describe both *reversible* and *irreversible* phenomena by means of the same evolution operator, $C(\mathcal{T}_{\Lambda_\kappa})$, of eq.(3). It produces, on the one hand, the double sign ($\pm$) and, on the other hand, eliminates "i " in the exponent of $U_{nmp}(\mathcal{T}_{\Lambda_\kappa})$. The operator, $U_u(\mathcal{T}_{\Lambda_\kappa})$, on the other hand, is formally the same for all field theories. The decisive idea in obtaining these results, contrary to what is customary, was to first solve the Schroedinger equation for the evolution operator and afterwards to quantize the theory. This new procedure presents the advantage that the Bohr quantization simplifies things and gives answer to the question, no matter whether a quantum interaction process is reversible or irreversible.

5 Conclusions and discussion

The measured T-asymmetry in the CPLEAR-experiment has been calculated from the Stochastic QFT in the framework of chronotopology. The input data consists in the rest masses of the particles and their chronotopological quantum numbers. The Hamiltonian densities of the fields are relativistically covariant and contain no approximation parameters and no terms spoiling Hermiticity of the theory. The negative chronotopological quantum numbers for antiparticles reflect the lower probability of their paths of propagation. This property is another expression for the lower abundance of the antimatter today in the universe. They also affect directly the difference of the forward and the backward oscillation of the K^0–strangeness.

Since the notion of the interaction proper-time neighborhood is a concept only of chronotopology eq. (12) cannot be derived by any other theory. Also, according to the time definition, no time exists prior to interactions processes causing the changes of observables, ΔO^j_λ, whose the time-elements, τ^j_λ, are the regular maps. This shows clearly that no time could exist prior to the creation of the universe according to chronotopology.

Stochastic QFT predicts a dependence of the T-asymmetry on the energy. The fact that this asymmetry in chronotopology depends on the quantum numbers and not on an operation like $t \to t' = -t$ makes clear that the attenuation of the antimatter density in the universe is a phenomenon due to the negative quantum numbers of the particles and their antiparticles. The same cause is responsible for the strong probability reduction for the propagation of antiparticles as compared to that of particles. Just this is the reason for the T-asymmetry measured by the CPLEAR-Collaboration.

Summarizing, the successful application of chronotopology to the solution presented shows the significance of the following three important facts:

(i) Dirac's proposition was correct, according to which every particle should have its own time variable in the many-particle Schroedinger equation [1].

(ii) Time-reversal has no impact on the increasing or decreasing of the entropy, because time may be defined as positive or as negative without affecting the description of physical processes.

(iii) The quantum fields as well as the wave functions become generalized random and infinitely divisible fields [5] in chronotopology.

Another important result following from (iii) above is that $C(\tau_\lambda)$ for $\tau_\lambda \in \mathcal{T}_{\Lambda_\kappa}$, as shown in Table I, is related to the Feynman path integral. By acting on the state vector $C(\tau_\lambda)\Psi(\tau_\lambda)$ and by letting $\Lambda(j,\sigma)$ take all values allowed for the quantum number j, then the state vector evolves along all corresponding paths.

The existence of the microscopic arrow of time has been demonstrated in the framework of QFT for the first time in [17]. The CPLEAR-experiment [28] is a beautiful verification of the theoretically predicted duality in the physical evolution by means of the quantum alternative: *Either T-symmetry* or *T-asymmetry*. This proves that the introduction of a time variable by means of the transformation, $t \rightarrow t' = -it$, in quantum theory or in the theory of relativity may be, if certain conditions are not fulfilled, not only unphysical [24] but, also, may contradict directly other undoubtedly established theories [27]. It is, therefore, interesting that some theoreticians are beginning to look skeptically at the imaginary time [6].

It is hoped that the results presented here are of some use to the numerous physicists working on the marvelously exciting time-enterprise.

Acknowledgment

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