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PHASE TRANSITION IN THE ELECTROWEAK THEORY

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Abstract. *Spontaneous symmetry breaking in the electroweak theory is investigated at finite temperature and non-zero chemical potential. We consider two sceneries $\mu^2 > m^2 > 0$ and $m^2 < 0 \leq \mu^2$. The dispersion relations and critical temperature are determined in the case of negative m^2 and all non-zero coupling constants. It is shown that the chemical potential affects significantly on the phase transition and the condensated matter.*

I. INTRODUCTION

Weinberg-Salam-Glashow theory is well known as a unification of weak and electromagnetic interactions. In this model the $SU(2) \times SU(1)$ symmetry group is the minimal one [1, 2]. However, the theory is only renormalizeable by Higgs mechanism, where the non - abelian gauge invariance is broken spontaneously (t' Hooft 1971) [3, 4]. This is the firsts realistic gauge theory that describes the experimental data with high accuracy. Furthermore, the mechanism of spontaneous symmetric breaking provides a good investigation of Bose - Einstein condensation [5, 6].

Our main aim is to present in detail the electroweak theory without fermions at finite temperature and non-zero chemical potential basing on the thermal field theory [7, 8]. In this connection, it is possible to consider our work as being complementary to result previously at zero temperature and the U(1) coupling constant $g' = 0$ [7, 9].

This paper is organized as follow. In Section II the formalism is introduced in the presence of non-zero chemical potential μ and a source term $I_\nu B^\nu$. Section III is devoted to the scenarios $0 < m^2 < \mu^2$. In Section IV the scenarios $m^2 < 0 \leq \mu^2$ is investigated. In section V the critical temperature in the electroweak theory is derived. Our conclusions are summarized in Section VI.

II. FORMALISM

We start from the Higgs sector of Lagrangian density in the electroweak theory basing on $SU(2) \times SU(1)$ symmetry

$$L = [(D_\mu - i\mu\delta_{0\mu})\,\Phi]^+ \,(D_\mu - i\mu\delta_{0\mu})\,\Phi - m^2\Phi^+\Phi - \lambda\left(\Phi^+\Phi\right)^2 - \frac{1}{4}F^a_{\mu\nu}F^{a\mu\nu} - \frac{1}{4}B_{\mu\nu}B^{\mu\nu} \quad (1)$$

where μ is chemical potential, the coupling constant $\lambda > 0$.

$$\begin{aligned} D_\mu &= \partial_\mu - igA_\mu^a \frac{\tau^a}{2} - ig'YB_\mu \\ F_{\mu\nu}^a &= \partial_\mu A_\nu^a - \partial_\nu A_\mu^a + g\epsilon_{abc}A_\mu^b A_\nu^c \\ B_{\mu\nu} &= \partial_\mu B_\nu - \partial_\nu B_\mu \end{aligned}$$

Here $a, b, c = 1, 2, 3$; $\mu,\ \nu = 0, 1, 2, 3$.

It is well known, the potential

$$V(\Phi^+\Phi) = -\left(\mu^2 - m^2\right)\Phi^+\Phi + \lambda(\Phi^+\Phi)^2 \tag{2}$$

is minimum at these values of scalar field

$$\begin{aligned} \Phi_0 &= 0 \\ \text{or} \qquad \Phi_0^+\Phi_0 &= \frac{\mu^2 - m^2}{2\lambda} = \phi_0^2 = \frac{v^2}{2} \end{aligned} \tag{3}$$

If $\mu^2 < m^2$ the solution stable is $\Phi_0 = 0$, if $\mu^2 > m^2$ it is stable at $\Phi_0^+\Phi_0 = \phi_0^2$

Introducing a source term $J_\nu B^\nu$ into the Lagrangian (1), i.e

$$L \to L + J_\nu B^\nu \tag{4}$$

where $J_\nu = J_0\delta_{0\nu}$, $< B_\nu >= 0$.

The Lagrangian density (4) becomes

$$\begin{aligned} L = &(\partial_\mu\Phi)^+(\partial_\mu\Phi) + i\mu\left[\Phi^+(\partial_0\Phi) - (\partial_0\Phi^+)\Phi\right] + \\ &+ \frac{1}{4}\left(g\tau_a A_\mu^a + g'B_\mu\right)\Phi^+\left(g\tau_a A^{a\mu} + g'B^\mu\right)\Phi + \\ &+ i\left[\partial_\mu\Phi^+\left(g\tau_a A_\mu^a + g'B_\mu\right)\Phi - \Phi^+\left(g\tau_a A^{a\mu} + g'B^\mu\right)\partial_\mu\Phi\right] + \\ &- \mu\Phi^+\left(g\tau_a A_0^a + g'B_0\right)\Phi + (\mu^2 - m^2)\Phi^+\Phi + \\ &- \lambda(\Phi^+\Phi)^2 - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - \frac{1}{4}B_{\mu\nu}B^{\mu\nu} + J_\nu B^\nu \end{aligned} \tag{5}$$

The equations of motion for scalar field Φ, gauge fields B_μ and A_μ , respectively, take the forms

$$-D_\mu D^\mu\Phi + \mu\left(g\tau_a A_0^a + g'B_0\right)\Phi + (\mu^2 - m^2)\Phi - 2\lambda(\Phi^+\Phi)\Phi = 0 \tag{6}$$

$$\partial^\mu B_{\mu\nu} + \frac{1}{2}ig'\left[(D_\mu\Phi)^+\Phi - \Phi^+(D_\mu\Phi)\right] - J_\nu = 0 \tag{7}$$

$$\partial^\mu F_{\mu\nu}^a + g\epsilon_{abc}A^{\mu b}F_{\mu\nu}^c + ig\left[\Phi^+\frac{\tau^a}{2}\partial_\nu\Phi - \partial_\nu\Phi^+\frac{\tau^a}{2}\Phi\right] + \frac{g^2}{2}A_\nu^a\Phi^+\Phi + 2g\mu\delta_{\nu 0}\Phi^+\frac{\tau^a}{2}\Phi = 0 \tag{8}$$

The vacuum expectation value of gauge field A_μ is determined from Eqs (3) and (6)

$$< A_0^a >= 0 \tag{9}$$

The current J_0 is derived from Eq (7) and the condition $< B_0 >= 0$

$$J_0 = 2g'\mu\phi_0^2 \tag{10}$$

By shifting the scalar field by

$$\Phi \to \Phi = \begin{pmatrix} 0 \\ \phi_0 \end{pmatrix} + \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ \chi \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ \chi + v \end{pmatrix} \tag{11}$$

where ϕ_0 is the new ground state expectation value

$$\phi_0 = \sqrt{\frac{\mu^2 - m^2}{2\lambda}} = \frac{v}{\sqrt{2}} \tag{12}$$

and χ is a real field (Higgs), which leads to the spontaneous breaking of symmetry. As it well known, the gauge fields are usually defined by

$$W_\mu^{(\pm)} = \frac{1}{\sqrt{2}} \left(A_\mu^1 \mp A_\mu^2 \right) \tag{13}$$

$$Z_\mu = W_\mu^3 = W^{3\mu} = \frac{g A_\mu^3 - g' B_\mu}{\left(g^2 + g'^2 \right)^{1/2}} = cos\theta A_\mu^3 - sin\theta B_\mu \tag{14}$$

$$A_\mu = \frac{g B_\mu + g' A_\mu^3}{\left(g^2 + g'^2 \right)^{1/2}} = sin\theta A_\mu^3 + cos\theta B_\mu \tag{15}$$

where θ is the Weinberg angle, $tg\theta = g'/g$.

Define two new coupling constants

$$g_W = g \frac{g}{\left(g^2 + g'^2 \right)^{1/2}} = g cos\theta \tag{16}$$

$$e = g \frac{g'}{\left(g^2 + g'^2 \right)^{1/2}} = g sin\theta \tag{17}$$

g_W is just gauge coupling constant, a e is the electric charge.

The masses of gauge bosons W, Z are given by

$$m_W^2 = \frac{1}{2} g^2 \phi_0^2 = \frac{1}{4} g^2 v^2 = \left(g_W^2 + e^2 \right) \frac{v^2}{4} \tag{18}$$

$$m_Z^2 = \frac{g^2 + g'^2}{2} \phi_0^2 = \frac{\left(g_W^2 + e^2 \right)^2}{g_W^2} \frac{v^2}{4} \tag{19}$$

$$\frac{m_W^2}{m_Z^2} = \frac{g_W^2}{g_W^2 + e^2} \tag{20}$$

i.e the $SU(2)$ symmetry breaking effect leads to mass different between the charge and neutral gauge bosons, $W_\mu^\pm$ and Z_μ.

The complete Lagrangian (5) that includes the Higgs sector and gauge part reads

$$\begin{aligned}
L = & \frac{1}{2}\partial_\mu\chi\partial^\mu\chi - \frac{i}{2}\mu\left[(\partial_0\chi^+)\chi - \chi^+(\partial_0\chi)\right] + \frac{1}{2}(\overline{\mu}^2 - \overline{m}^2)(v+\chi)^2 + \\
& - \frac{\lambda}{4}(v+\chi)^4 + \frac{1}{4}\mu v^2\left[\frac{g_W^2+e^2}{g_W}Z_0 + 2eA_0\right]\chi + \\
& + \frac{1}{2}W_\mu^{(+)}\left(\Box g^{\mu\nu} - \partial^\mu\partial\nu + m_W^2\right)W_\nu^{(-)} + \\
& + \frac{1}{2}Z_\mu\left(\Box g^{\mu\nu} - \partial^\mu\partial\nu + m_Z^2\right)Z_\nu + \frac{1}{2}A_\mu\left(\Box g^{\mu\nu} - \partial^\mu\partial\nu\right)A_\nu + \\
& + \frac{g_W^2}{2}\left(Z_\mu \wedge W_\nu^{(-)}\right)\left(Z^\mu \wedge W^{\nu(+)}\right) + \\
& - \frac{g_W^2+e^2}{4}\left(W_\mu^{(+)} \wedge W_\nu^{(-)}\right)\left(W^{\mu(+)} \wedge W^{\nu(-)}\right) + \\
& - \frac{i}{2}g_W\left(\partial_\mu W_\nu^{(+)} - \partial_\nu W_\mu^{(+)}\right)\left(Z^\mu \wedge W^{\nu(+)}\right) + \\
& + \frac{i}{2}g_W\left(\partial_\mu W_\nu^{(-)} - \partial_\nu W_\mu^{(-)}\right)\left(Z^\mu \wedge W^{\nu(-)}\right) + \\
& + \frac{i}{2}g_W\left(\partial_\mu Z_\nu - \partial_\nu Z_\mu\right)\left(W_\mu^{(+)} \wedge W_\nu^{(-)}\right) + \\
& + ie\left[F_{\mu\nu}^{(+)}\left(A^\mu \wedge W^{\nu(+)}\right)\right] + \left[F_{\mu\nu}^{(-)}\left(A^\mu \wedge W^{\nu(-)}\right)\right] + \\
& + \frac{ie}{2}G_{\mu\nu}\left(W^{\mu(+)} \wedge W^{\nu(-)}\right) + \frac{e^2}{2}\left(A_\mu \wedge W_\nu^{(+)}\right)\left(A^\mu \wedge W^{\nu(-)}\right)
\end{aligned} \tag{21}$$

where

$$F_{\mu\nu}^{(\pm)} = \partial_\mu W_\nu^{(\pm)} - \partial_\nu W_\mu^{(\pm)} \mp ig_W\left(Z^\mu \wedge W_\nu^{(\mp)}\right) \tag{22}$$

$$\overline{\mu} = \mu - \frac{1}{2}(g^2+g'^2)^{1/2}Z_\mu = \mu - \frac{1}{2}\frac{g_W^2+e^2}{g_W}Z_\mu \tag{23}$$

$$\overline{m}^2 = m^2 + \frac{g^2}{2}W_\mu^{(+)}W_\mu^{(-)} = m^2 + \frac{g_W^2+e^2}{2}W_\mu^{(+)}W_\mu^{(-)} \tag{24}$$

Let us consider in detail two scenarios $m^2 > 0$ and $m^2 < 0$, the chemical potential μ play role as a parameter acting on the breaking of symmetry.

III. FIRST SCENARIO: $m^2 > 0,\ e = g' = 0$

In this case $g = g_W$, $m_{W_\pm} = m_{W_0} = \frac{1}{2}gv$. If $\mu^2 < m^2$ the $SU(2)\times U(1)_Y \times SU(3)$ symmetry is exact, the theory is relativistic. If $\mu^2 > m^2 > 0$, the $U(1)_Y$ symmetry is broken. Take the ansatz as follow

$$\begin{aligned}
W_3^{(+)} &= W_3^{(-)} = I \neq 0, \qquad Z_0 = W_0^{(3)} = K \neq 0 \\
W_{1,2}^{(\pm)} &= W_0^{(\pm)} = W_{1,2}^{(3)} = W_3^{(3)} = 0
\end{aligned} \tag{25}$$

In the Mean Field Approximation (MFA), where all field derivates had been setting to zero, the effective potential becomes

$$\begin{aligned} V &= -\frac{g^2}{2}\left(Z_0 \wedge W_3^{(-)}\right)\left(Z_0 \wedge W^{3(+)}\right) + \\ &+ \frac{g^2}{4}\left(W_i^{(+)} \wedge W_j^{(-)}\right)\left(W^{i(+)} \wedge W^{j(-)}\right) + \\ &- \frac{1}{2}\left[\left(\mu - \frac{1}{2}gZ_0\right)^2 - \left(m^2 + \frac{1}{2}g^2 W_3^{(+)}W_3^{(-)}\right)\right](v+\chi)^2 + \\ &+ \frac{\lambda}{4}(v+\chi)^2 \\ &= -g^2 I^2 K^2 - \left(\mu - \frac{gK}{2}\right)^2 \phi^2 + \left(m^2 + \frac{g^2 I^2}{2}\right)\phi^2 + \lambda\phi^4 \end{aligned} \tag{26}$$

The physical processes satisfies the stationary condition at $\phi = \phi_0$

$$\frac{\partial V}{\partial I}_{|\phi=\phi_0} = 0, \qquad \frac{\partial V}{\partial K}_{|\phi=\phi_0} = 0, \qquad \frac{\partial V}{\partial \phi}_{|\phi=\phi_0} = 0$$

which leads to the system of equations

$$\left(K^2 - \frac{1}{2}\phi_0^2\right) I = 0 \tag{27}$$

$$\left(2I^2 + \frac{1}{2}\phi_0^2\right) K = \frac{\mu}{g}\phi_0^2 \tag{28}$$

$$\left[\left(\mu - \frac{1}{2}gK\right)^2 - m^2 - \frac{1}{2}g^2 I^2 - 2\lambda\phi_0^2\right]\phi_0 = 0 \tag{29}$$

For $\mu^2 > m^2$ (i.e $v > 0$), the ground state expectation value $\phi_0 > 0$, $I \neq 0$, Eq. (27) yields

$$K = \frac{\sqrt{2}}{2}\phi_0 > 0 \tag{30}$$

Substituting (30) into Eq. (29), we have

$$(\mu^2 - m^2) + \left(\frac{g^2}{4} - 2\lambda\right)\phi_0^2 - \frac{3g\mu}{2\sqrt{2}}\phi_0 = 0 \tag{31}$$

It's solution reads

$$\phi_0 = \frac{1}{\sqrt{2}(8\lambda - g^2)}\left[\sqrt{(g^2 + 64\lambda)\mu^2 - 8(8\lambda - g^2)m^2} - 3g\mu\right] \tag{32}$$

For $g^2 \leq 8\lambda$ the potential has minimum at the solution stable ϕ_0. At the critical value $\mu = m$ there is **a second order phase transition.**

IV. SECOND SCENARIO: $m^2 < 0 \leq \mu^2$

We focus on the dynamics in the second case $m^2 < 0$ in the presence of chemical potential $\mu \geq 0$. Here, it is well known, the symmetry is broken spontaneously $SU(2) \times U(1)_Y \to U(1)_{EM}$.

Let us consider the effective potential in MFA. It is defined from the Lagrangian (1)

$$V = -L_{MFT}.$$

IV.1. Case $g \neq 0$ and $g' = 0$, $\phi_0 = const$

Firstly we consider a homogenous ground state solution with ϕ_0 being constant, which does not break the rotational in variance, i.e

$$W_a^{(\pm)} = 0, \qquad Z_a = 0, \qquad \chi_0 = 0, \qquad A_0 = 0 \tag{33}$$

In this case, due to definition in (17) $g' = 0$ implies $e = 0$. Therefore

$$\begin{aligned} g &= \left(g_W^2 + e^2\right)^{1/2} = g_W && (34) \\ m_W^2 &= m_Z^2 = \frac{1}{2} g^2 \phi_0^2 && (35) \end{aligned}$$

The effective potential in MFA takes the form

$$\begin{aligned} V = & -\frac{1}{2} g_W^2 \left(Z_0 \wedge W_0^{(-)}\right)\left(Z^0 \wedge W^{0(+)}\right) + \\ & + \frac{1}{4} g_W^2 \left(W_0^{(+)} \wedge W_0^{(-)}\right)\left(W_0^{(+)} \wedge W^{0(-)}\right) + \\ & - \left(\overline{\mu}^2 - \overline{m}^2\right)\phi_0^2 + \lambda \phi_0^4 \end{aligned} \tag{36}$$

where

$$\begin{aligned} \overline{\mu} &= \mu - \frac{1}{2} g Z_0 && (37) \\ \overline{m}^2 &= m^2 + \frac{1}{2} g^2 W_0^{(+)} W_0^{(-)} && (38) \end{aligned}$$

The equations of motion become

$$\left(i\partial_0 W_0^{(+)} + 2\mu W_0^{(+)}\right)\phi_0 = 0 \tag{39}$$

$$\frac{\partial V}{\partial Z_0} = g\left(\frac{1}{2} g Z_0 - \mu\right)\phi_0 = 0 \tag{40}$$

$$\frac{\partial V}{\partial W_0^{(\pm)}} = \frac{1}{2} g^2 \phi_0^2 W_0^{(\pm)} = 0 \tag{41}$$

and

$$\frac{\partial V}{\partial \phi_0} = \left[\left(\mu - \frac{g}{2} Z_0\right)^2 - m^2 - 2\lambda\phi_0^2 - \frac{i}{2} g \partial_0 Z_0 + \frac{g^2}{2} W_0^{(+)} W_0^{(-)}\right]\phi_0 = 0 \tag{42}$$

It is easily to find the symmetry solution $\phi_0 = 0$ and other solutions of system of Eqs (40) - (42)

$$Z_0 = \frac{2\mu}{g} \tag{43}$$

$$W_0^{(\pm)} = 0 \tag{44}$$

and

$$\phi_0 = -\frac{m^2}{2\lambda}; \qquad Z_0 = \frac{2\mu}{g}; \qquad W_0^{(\pm)} = 0 \tag{45}$$

i.e the ground state expectation values of vector fields are well determined physical quantities.The solutions (45) is shown that spontaneous $U(1)_Y$ symmetry breaking exits only for negative m^2.

Substituting (45) into (38), we obtain the effective chemical potential and the squared mass, respectively

$$\overline{\mu} = 2\mu, \qquad \overline{m}^2 = m^2.$$

IV.2. Case $g \neq 0$ and $g' \neq 0$, $m^2 < 0 \leq \mu^2$

In this case, the ground state (45) describes spontaneous breaking $SU(2) \times U(1)_Y$ to $U(1)_{EM}$ and preserve of rotational invariance.

The propagators for massive vector gauge boson is given by

$$S_{\mu\nu}(k) = \frac{i}{k^2 - m_W^2}\left[g_{\mu\nu} - (1-\xi)\frac{k^\mu k^\nu}{k^2 - \xi m_W^2}\right] \tag{46}$$

Next we consider finite temperature by "imagine time" formalism. The matrices corresponding to (46) in t'Hooft - Feymann $\xi = 1$ takes the form

$$S^{-1}_{\mu\nu}(k) = \begin{pmatrix} \left[\omega^2 - \left(\overrightarrow{k}^2 + \frac{1}{2}g^2\phi_0^2\right)\right] g_{\mu\nu} & 2i\mu\omega \\ -2i\mu\omega & \left[\omega^2 - \left(\overrightarrow{k}^2 + \frac{1}{2}g^2\phi_0^2\right)\right] g_{\mu\nu} \end{pmatrix} \tag{47}$$

It's dispersion relations is determined from $det S^{-1} = 0$

$$\omega_\pm = \sqrt{\mu^2 + \overrightarrow{k}^2 + \frac{1}{2}g^2\phi_0^2} \pm \mu \tag{48}$$

In infrared it becomes

$$\omega_\pm \simeq \sqrt{\mu^2 + \frac{1}{2}g^2\phi_0^2} \pm \mu \tag{49}$$

That means the chemical potential leads to spliting the quantum masses of two charged vector boson.

Similary, the inverse propagator of neutral gauge boson Z_μ and photon A_μ is

$$G^{-1}_{\mu\nu}(k) = \begin{pmatrix} \left(\omega^2 - \overrightarrow{k}^2\right) g_{\mu\nu} & 2i\mu\omega \\ -2i\mu\omega & \left[\omega^2 - \left(\overrightarrow{k}^2 + m_Z^2\right)\right] g_{\mu\nu} \end{pmatrix} \tag{50}$$

where

$$m_Z^2 = \frac{1}{2}(g^2 + g'^2)\phi_0^2 = \frac{1}{4}(g^2 + g'^2)v^2$$

When $k \to 0$, the equation $detG^{-1}_{\mu\nu} = 0$ reads

$$detG^{-1}(k) = \omega^4 - \omega^2(m_Z^2 - 4\mu^2) = 0 \tag{51}$$

Their dispersion relations are

$$\omega_{1,2}^2 = m_Z^2 - 4\mu^2 = (m_Z + 2\mu)(m_Z - 2\mu) \tag{52}$$

$$\omega_1 = \frac{(g^2 + g'^2)^{1/2} v}{2} + 2\mu \tag{53}$$

$$\omega_2 = \frac{(g^2 + g'^2)^{1/2} v}{2} - 2\mu \tag{54}$$

V. PHASE TRANSITION IN THE ELECTROWEAK THEORY

We consider the scalar field in the presence of non - zero chemical potential and temperature.

The equation of motion for ϕ reads

$$(\mu^2 - m^2 - 4\lambda\phi_0^2 - 3\lambda\chi^2 - \frac{1}{4}g^2 W_\mu^{(+)} W_\mu^{(-)} + \frac{g^2 + g'^2}{8} Z_\mu^2 + 2g'\mu B_\mu)\phi = 0 \tag{55}$$

When $\phi \to \phi_0$ it is shown [7] that all effective fields and chemical potential are very smaller than the critical temperature T_C.

When the quantum state is equilibrium, the fluctuations haven't influences significant to physical properties of system. If the conditions charge, these fluctuations could be spread and the quantum system becomes instable, then the phase transition leads it to new stable properties.

At the transition temperature $\phi_0 = 0$, due to the finite temperature part of propagators [10] one can determine the thermal average of squared scalar and gauge vector fields

$$< \chi^2 >= \frac{T^2}{12}; \qquad < W_{\mu i}^2 >= \frac{T^2}{8} \tag{56}$$

Substituting (56) into (55), we obtain the critical temperature

$$T_C^2 = \frac{16(\mu^2 - m^2)}{16\lambda + 3g^2 + g'^2}$$

or equivalently

$$T_C^2 = \frac{4(\mu^2 - m^2)}{2\lambda + e^2(1 + 2cos^2\theta)/sin^2 2\theta} \tag{57}$$

It is shown that the phase transition depends significantly on the chemical potential and the electric charge.

VI. DISCUSSION AND CONCLUSION

In the above sections the Weinberg Salam Glashow without fermions is considered at finite temperature and density. The dispersion relations are obtained, where the chemical potential acts to mechanism of spontaneous breaking of symmetry and it leads to splitting the quantum masses of vector bosons. The critical temperature has been directly derived in the mean-field approximation. The phase transition is second order one.

Linde [11] and Kapusta [7] have pointed out that at fixed temperature the condensation of the $W^{\pm}$ mesons should occur at higher densities than the symmetry restoring density. However, the finite density of charged fermions didnt affect on the results because its interactions and electromagnetic one are different. Eventhough strong electromagnetic could lead to the deconfinement Miransky [9] and other authors [12] have investigated a similar model, which includes three massless vector boson A_μ^a and two doublets $\left(K^+, K^0\right)$ and $\left(K^-, K^0\right)$.

Our next paper is intended to be devoted to the Weinberg Salam model including both bosonic and fermionic parts and to numerical calculations at finite temperature and density.

In conclusion, we would like to emphasize that the spontaneous symmetry violation and symmetry restoration at high temperature depend on the dynamics of the theory that is concerned with the physical processes.

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